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Alam et al.

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(45) **Date of Patent: Jul. 8, 2025**

(54) **SYSTEMS AND METHODS FOR IMPLEMENTING A REPEATABLE NETWORK ARCHITECTURE**

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(73) Assignee: **Aviatrix Systems, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 54 days.

(21) Appl. No.: **17/330,370**

(22) Filed: **May 25, 2021**

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(60) Provisional application No. 63/190,746, filed on May 19, 2021, provisional application No. 63/038,701, filed on Jun. 12, 2020.

(51) **Int. Cl.**
H04L 65/102 (2022.01)
H04L 41/08 (2022.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 41/0843*** (2013.01); ***H04L 41/0886*** (2013.01); ***H04L 45/02*** (2013.01); ***H04L 45/38*** (2013.01); ***H04L 65/102*** (2013.01)

(58) **Field of Classification Search**
CPC ... H04L 45/02; H04L 65/102; H04L 41/0886; H04L 41/0843
See application file for complete search history.

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Primary Examiner — Sandarva Khanal
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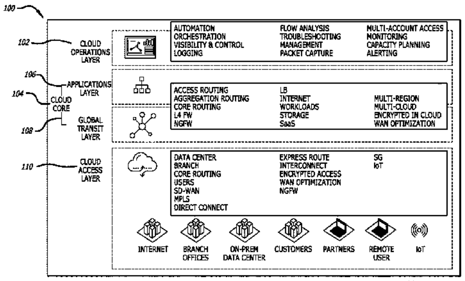
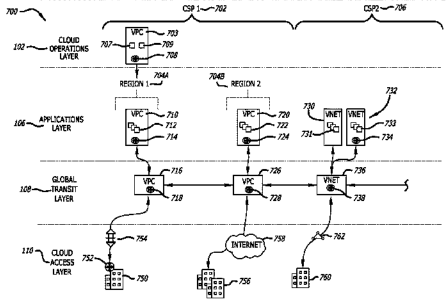
(57) **ABSTRACT**

A cloud computing system built in accordance with a repeatable network architecture is disclosed that includes a controller, a first set of spoke gateways and a first transit gateway. The controller is configured to deploy the first set of spoke gateways in a first cloud thereby forming an applications layer of the repeatable network architecture, deploy the first transit gateway in the first cloud thereby forming a global transit layer of the repeatable network architecture, and establish communicative couplings between each of the first set of spoke gateways and the first transit gateway. The controller is also configured to deploy a first set of spoke VPCs within the first cloud, wherein each of the spoke VPCs has deployed therein one of the first set of spoke gateways, and a first transit VPC within the first cloud, wherein the first transit gateway is deployed in the first transit VPC.

20 Claims, 15 Drawing Sheets





(51) **Int. Cl.**

H04L 41/084	(2022.01)
H04L 45/00	(2022.01)
H04L 45/02	(2022.01)

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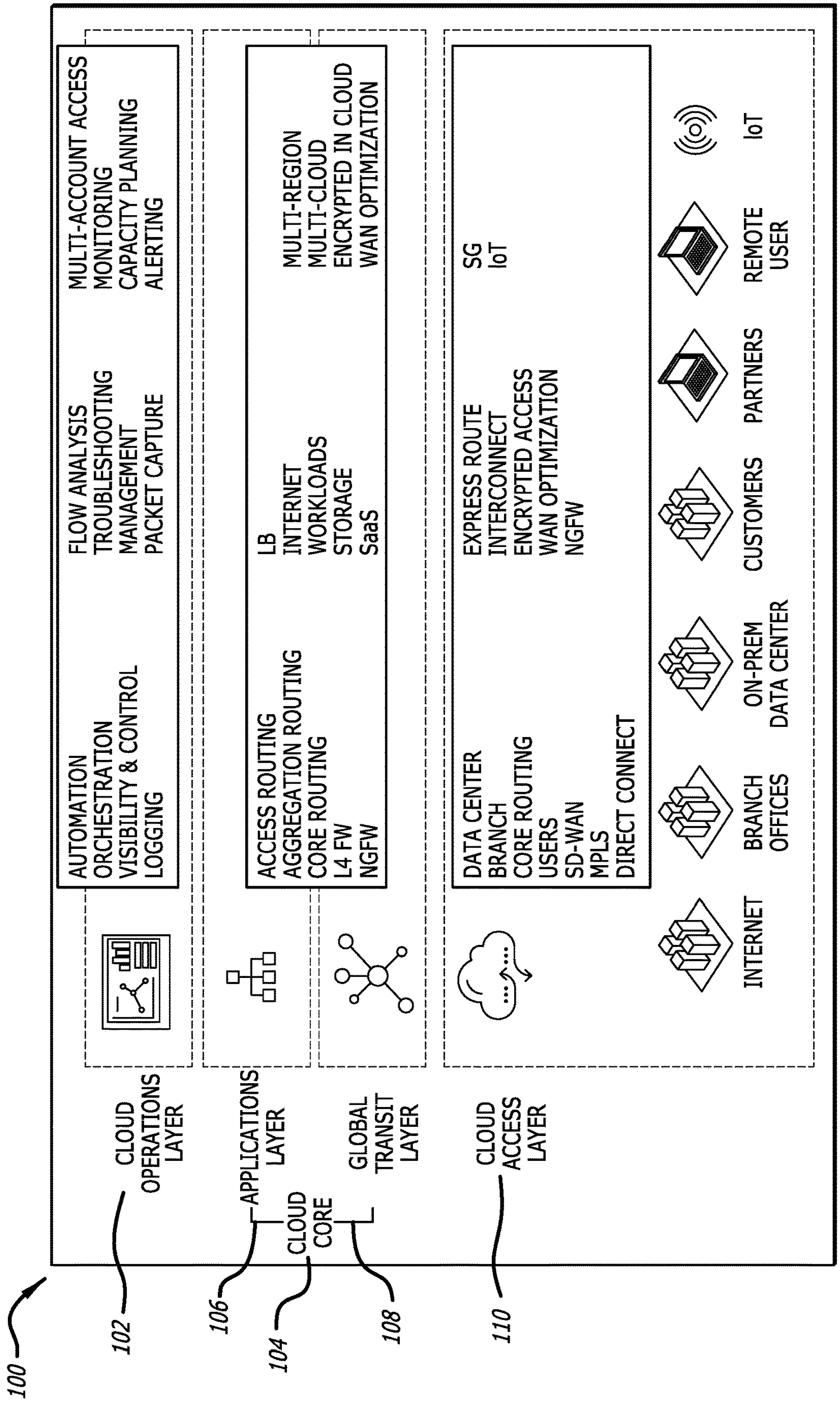

100
102
CLOUD OPERATIONS LAYER
AUTOMATION
ORCHESTRATION
VISIBILITY & CONTROL
LOGGING
FLOW ANALYSIS
TROUBLESHOOTING
MANAGEMENT
PACKET CAPTURE
MULTI-ACCOUNT ACCESS
MONITORING
CAPACITY PLANNING
ALERTING
106
APPLICATIONS LAYER
104
CLOUD CORE
108
GLOBAL TRANSIT LAYER
ACCESS ROUTING
AGGREGATION ROUTING
CORE ROUTING
L4 FW
NGFW
LB
INTERNET
WORKLOADS
STORAGE
SaaS
MULTI-REGION
MULTI-CLOUD
ENCRYPTED IN CLOUD
WAN OPTIMIZATION
110
CLOUD ACCESS LAYER
DATA CENTER
BRANCH
CORE ROUTING
USERS
SD-WAN
MPLS
DIRECT CONNECT
EXPRESS ROUTE
INTERCONNECT
ENCRYPTED ACCESS
WAN OPTIMIZATION
NGFW
5G
IoT
INTERNET
BRANCH OFFICES
ON-PREM DATA CENTER
CUSTOMERS
PARTNERS
REMOTE USER
IoT

FIG. 1

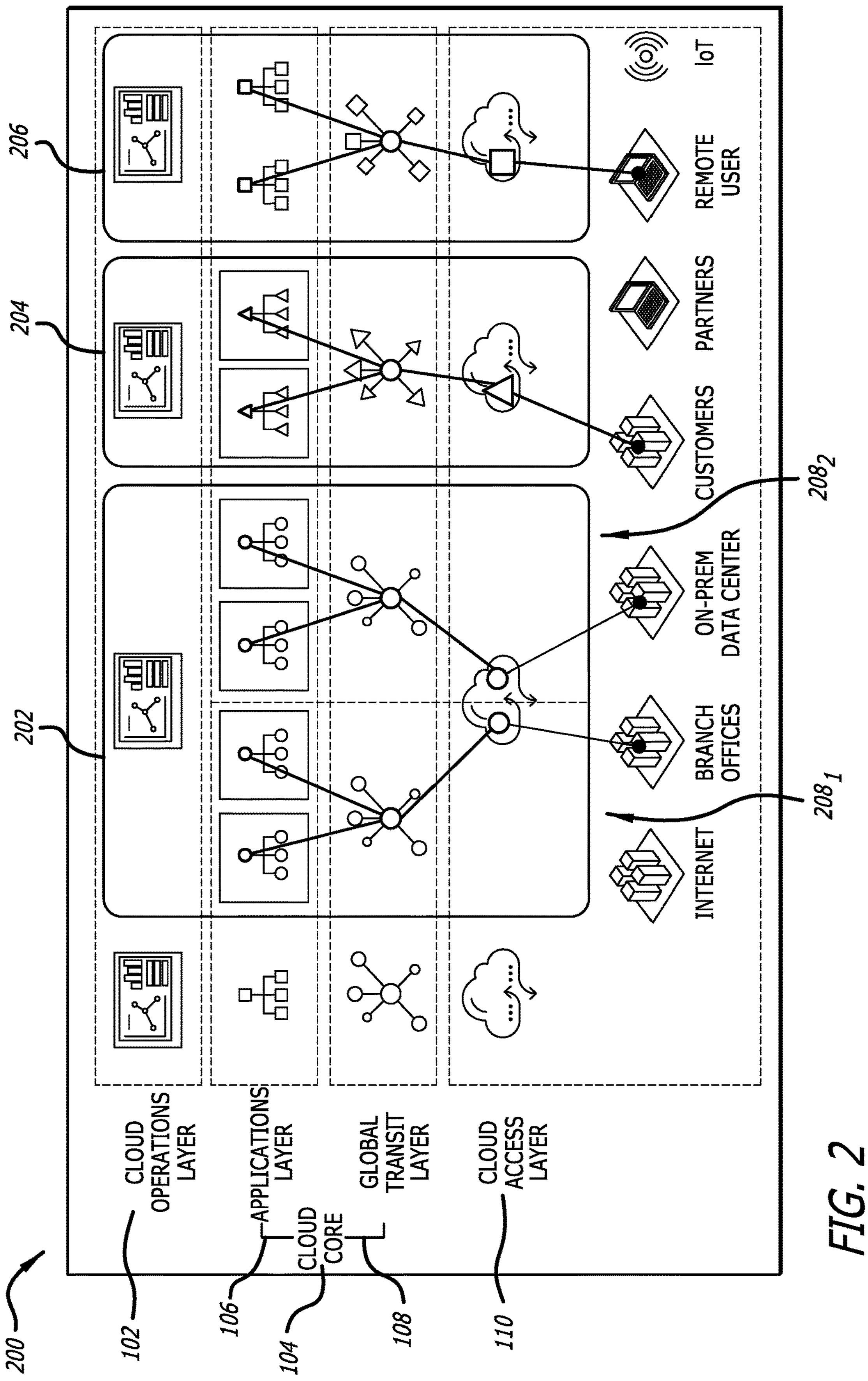
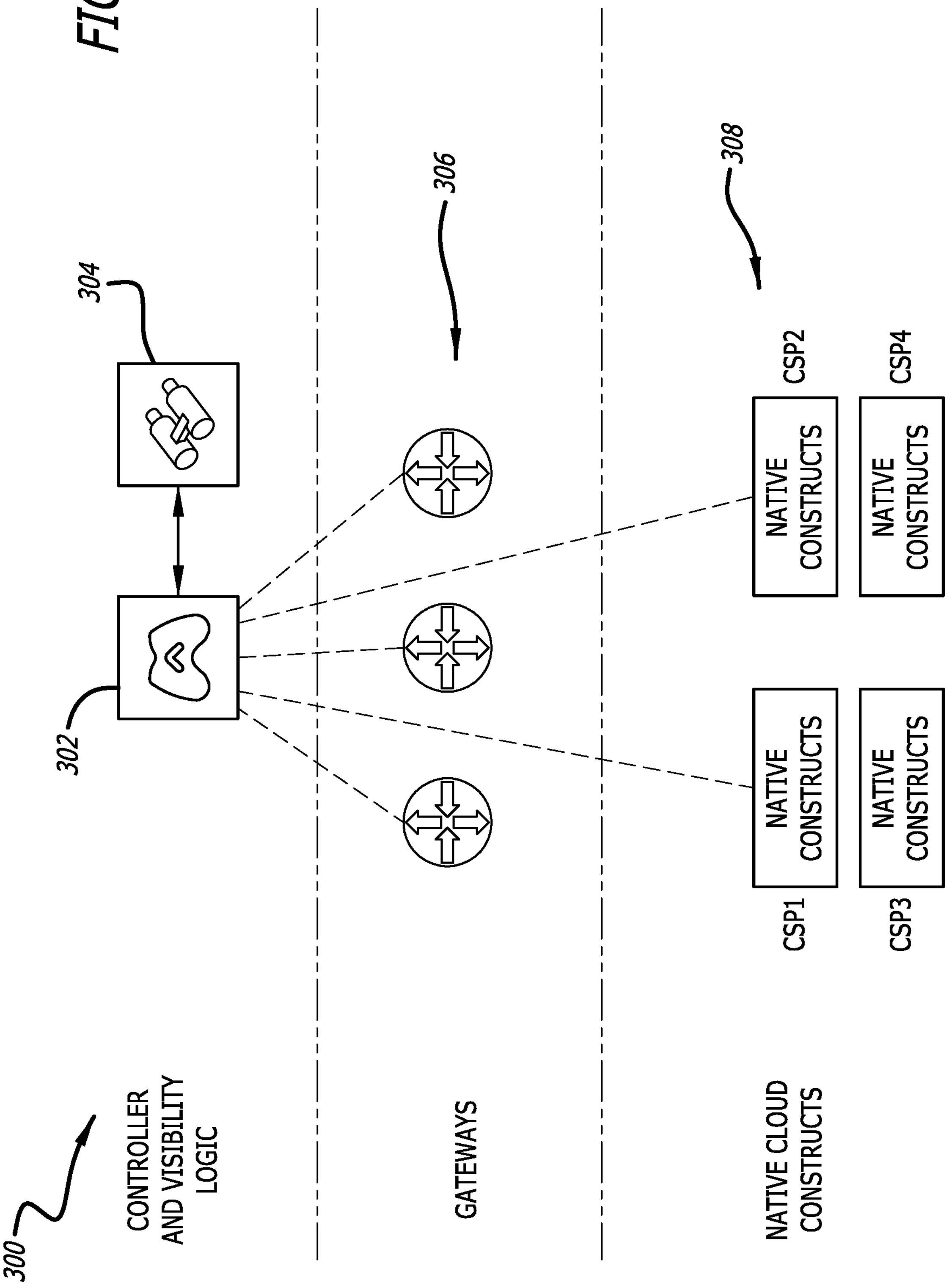

200
102
106
104
108
110
CLOUD OPERATIONS LAYER
APPLICATIONS LAYER
CLOUD CORE
GLOBAL TRANSIT LAYER
CLOUD ACCESS LAYER
202
204
206
208_1
208_2
INTERNET
BRANCH OFFICES
ON-PREM DATA CENTER
CUSTOMERS
PARTNERS
REMOTE USER
IoT

FIG. 2

FIG. 3


300
CONTROLLER AND VISIBILITY LOGIC
302
304
GATEWAYS
306
NATIVE CLOUD CONSTRUCTS
308
CSP1
NATIVE CONSTRUCTS
CSP2
NATIVE CONSTRUCTS
CSP3
NATIVE CONSTRUCTS
CSP4
NATIVE CONSTRUCTS

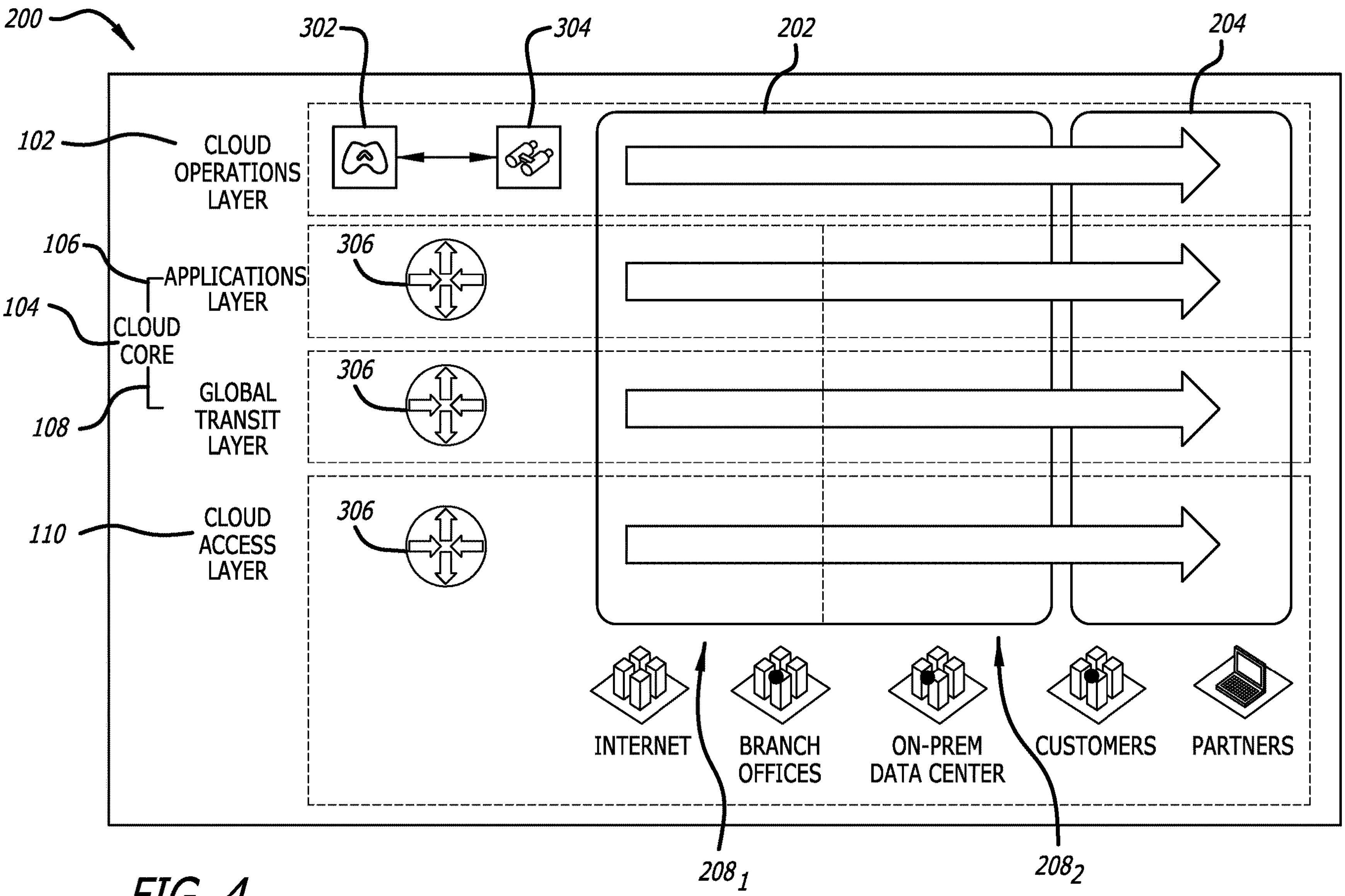

200
302
304
202
204
102
CLOUD OPERATIONS LAYER
106
APPLICATIONS LAYER
104
CLOUD CORE
108
GLOBAL TRANSIT LAYER
110
CLOUD ACCESS LAYER
306
306
306
INTERNET
BRANCH OFFICES
ON-PREM DATA CENTER
CUSTOMERS
PARTNERS
208 1
208 2

FIG. 4

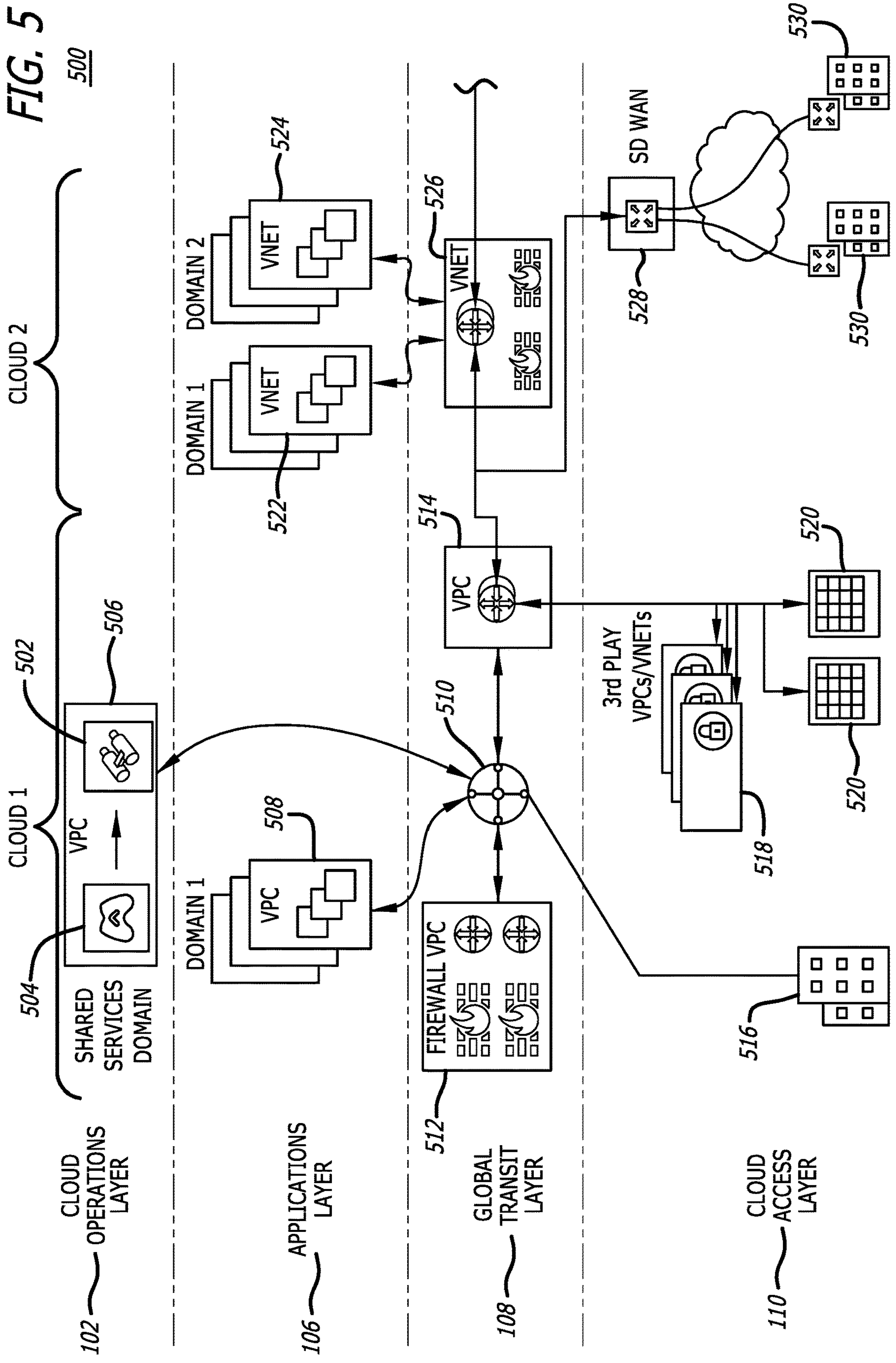
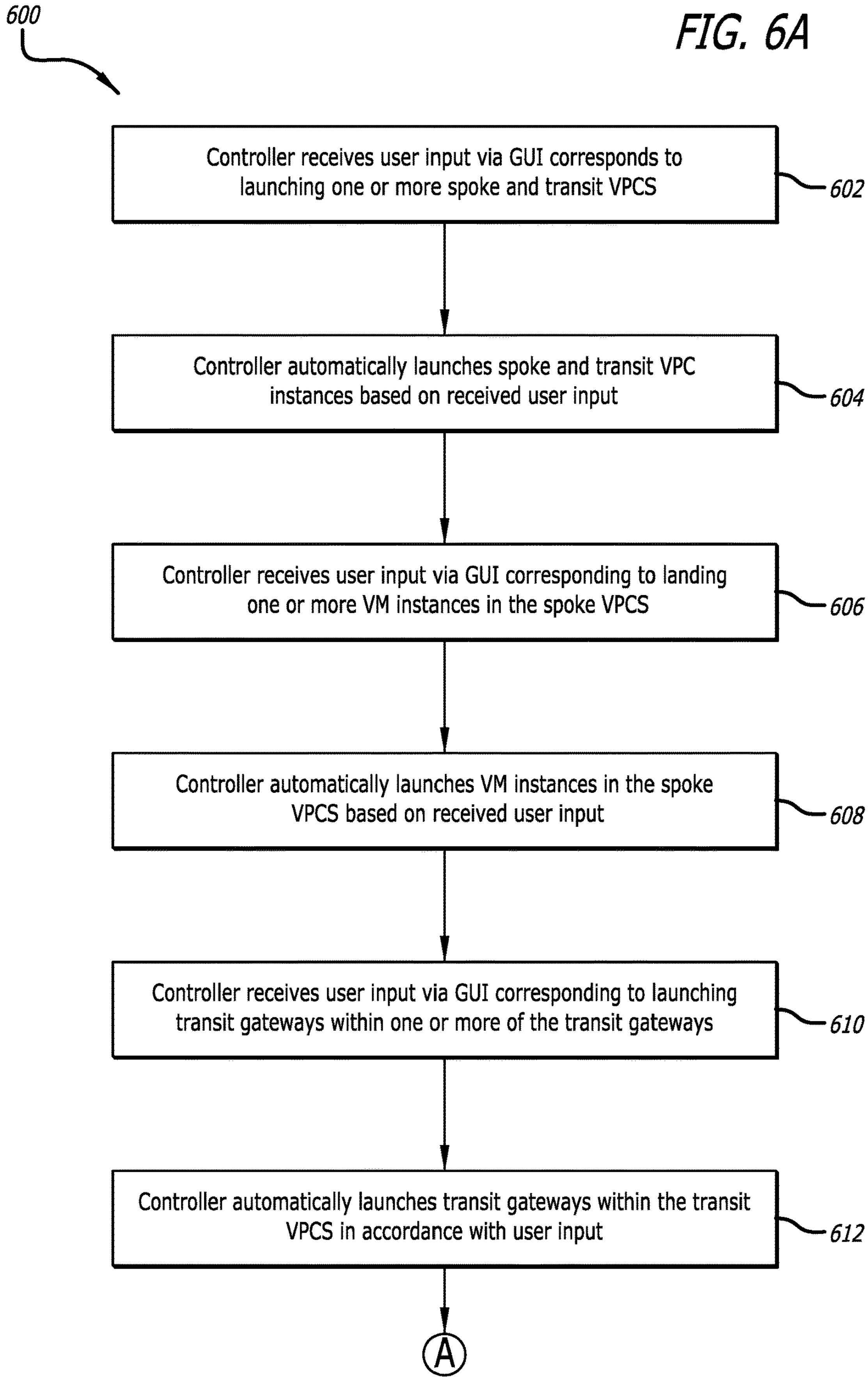


FIG. 5

500
CLOUD 1
CLOUD 2
102
CLOUD OPERATIONS LAYER
SHARED SERVICES DOMAIN
504
VPC
502
506
106
APPLICATIONS LAYER
DOMAIN 1
VPC
508
DOMAIN 1
VNET
522
DOMAIN 2
VNET
524
108
GLOBAL TRANSIT LAYER
512
FIREWALL VPC
510
514
VPC
526
VNET
110
CLOUD ACCESS LAYER
516
518
3rd PLAY VPCs/VNETs
520
520
528
SD WAN
530
530

FIG. 6A


600
Controller receives user input via GUI corresponds to launching one or more spoke and transit VPCS
602
Controller automatically launches spoke and transit VPC instances based on received user input
604
Controller receives user input via GUI corresponding to landing one or more VM instances in the spoke VPCS
606
Controller automatically launches VM instances in the spoke VPCS based on received user input
608
Controller receives user input via GUI corresponding to launching transit gateways within one or more of the transit gateways
610
Controller automatically launches transit gateways within the transit VPCS in accordance with user input
612
A

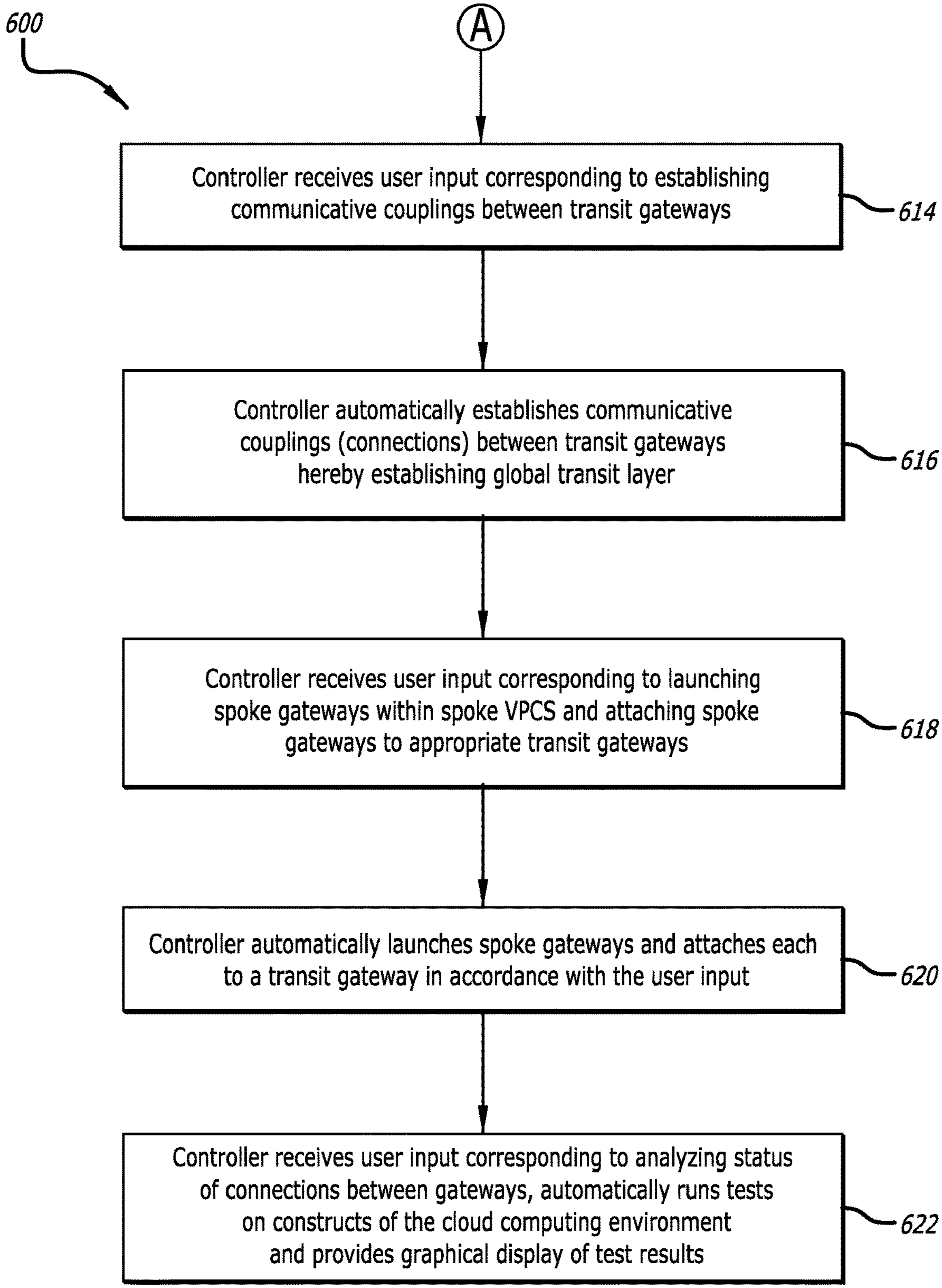

600
A
Controller receives user input corresponding to establishing communicative couplings between transit gateways
614
Controller automatically establishes communicative couplings (connections) between transit gateways hereby establishing global transit layer
616
Controller receives user input corresponding to launching spoke gateways within spoke VPCS and attaching spoke gateways to appropriate transit gateways
618
Controller automatically launches spoke gateways and attaches each to a transit gateway in accordance with the user input
620
Controller receives user input corresponding to analyzing status of connections between gateways, automatically runs tests on constructs of the cloud computing environment and provides graphical display of test results
622

FIG. 6B

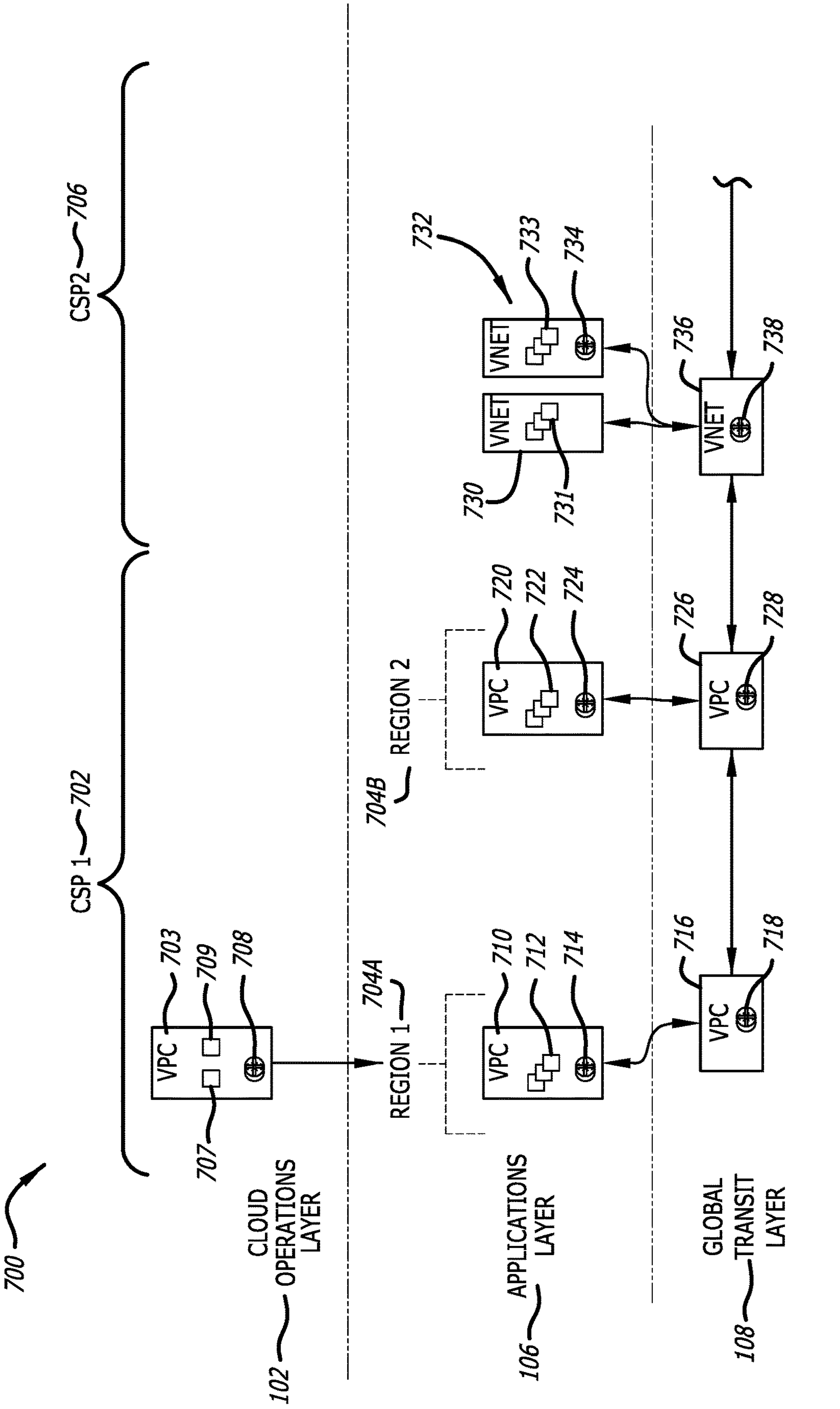

700
CLOUD OPERATIONS LAYER
102
APPLICATIONS LAYER
106
GLOBAL TRANSIT LAYER
108
CSP 1
702
CSP2
706
VPC
703
707
709
708
REGION 1
704A
VPC
710
712
714
VPC
716
718
REGION 2
704B
VPC
720
722
724
VPC
726
728
VNET
730
731
VNET
732
733
734
VNET
736
738

FIG. 7A

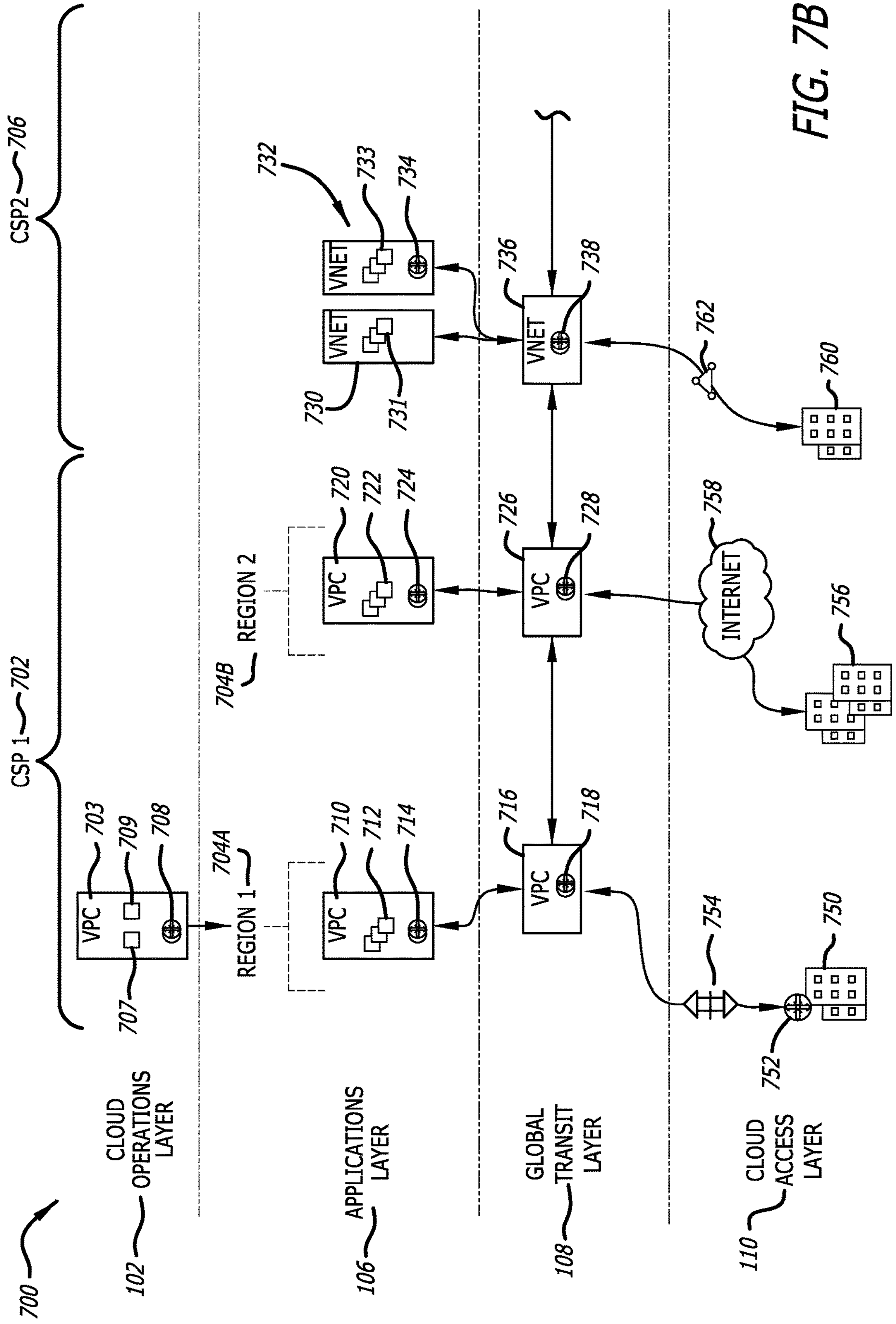

700
102
CLOUD OPERATIONS LAYER
106
APPLICATIONS LAYER
108
GLOBAL TRANSIT LAYER
110
CLOUD ACCESS LAYER
CSP 1
702
CSP2
706
VPC
703
707
709
708
REGION 1
704A
REGION 2
704B
VPC
710
712
714
VPC
720
722
724
VNET
730
731
VNET
732
733
734
VPC
716
718
VPC
726
728
VNET
736
738
754
752
750
INTERNET
758
756
762
760

FIG. 7B

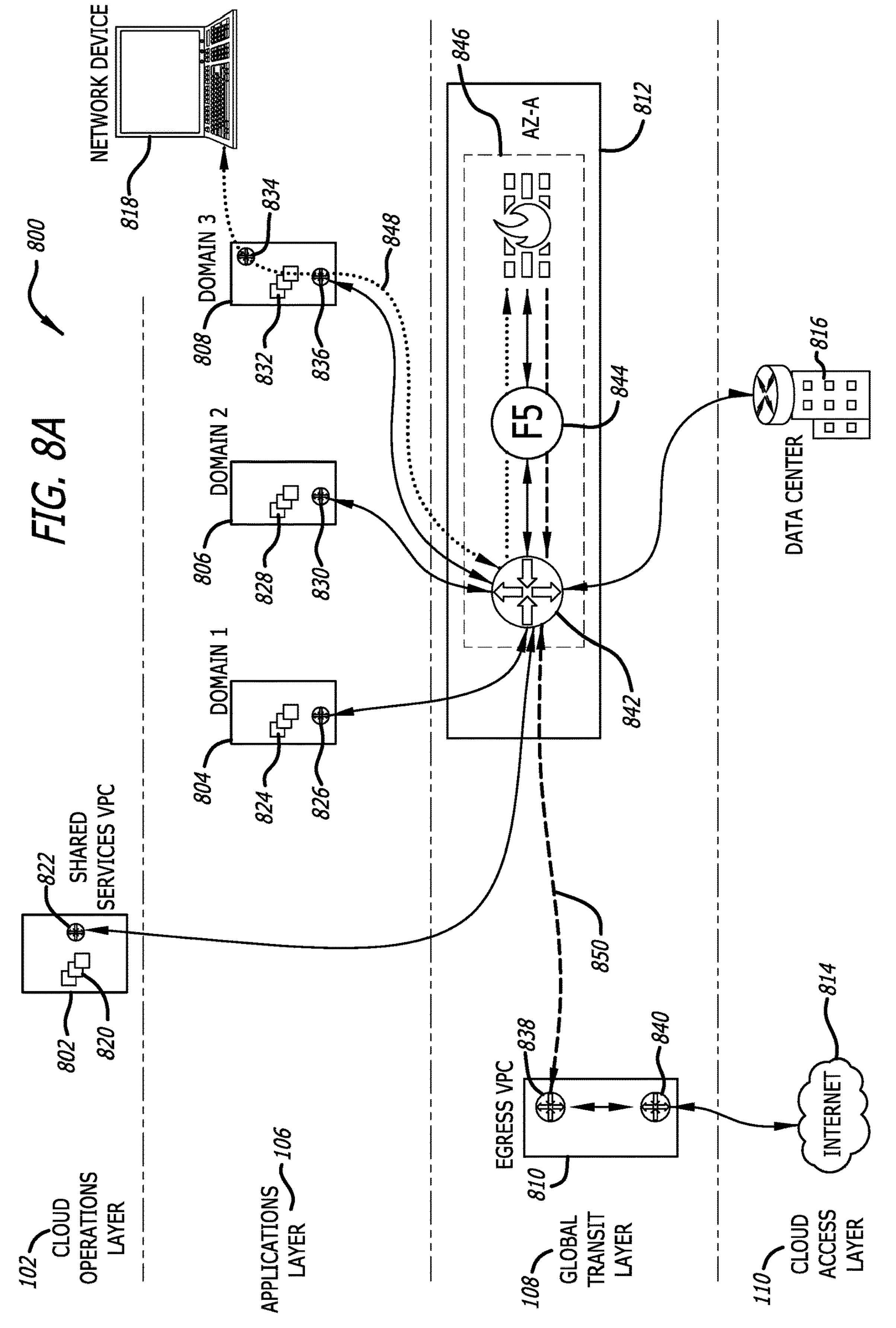


FIG. 8A

800
102 CLOUD OPERATIONS LAYER
APPLICATIONS LAYER 106
108 GLOBAL TRANSIT LAYER
110 CLOUD ACCESS LAYER
SHARED SERVICES VPC
802
820
822
DOMAIN 1
804
824
826
DOMAIN 2
806
828
830
DOMAIN 3
808
832
834
836
NETWORK DEVICE
818
848
846
AZ-A
812
F5
844
842
DATA CENTER
816
850
EGRESS VPC
810
838
840
INTERNET
814

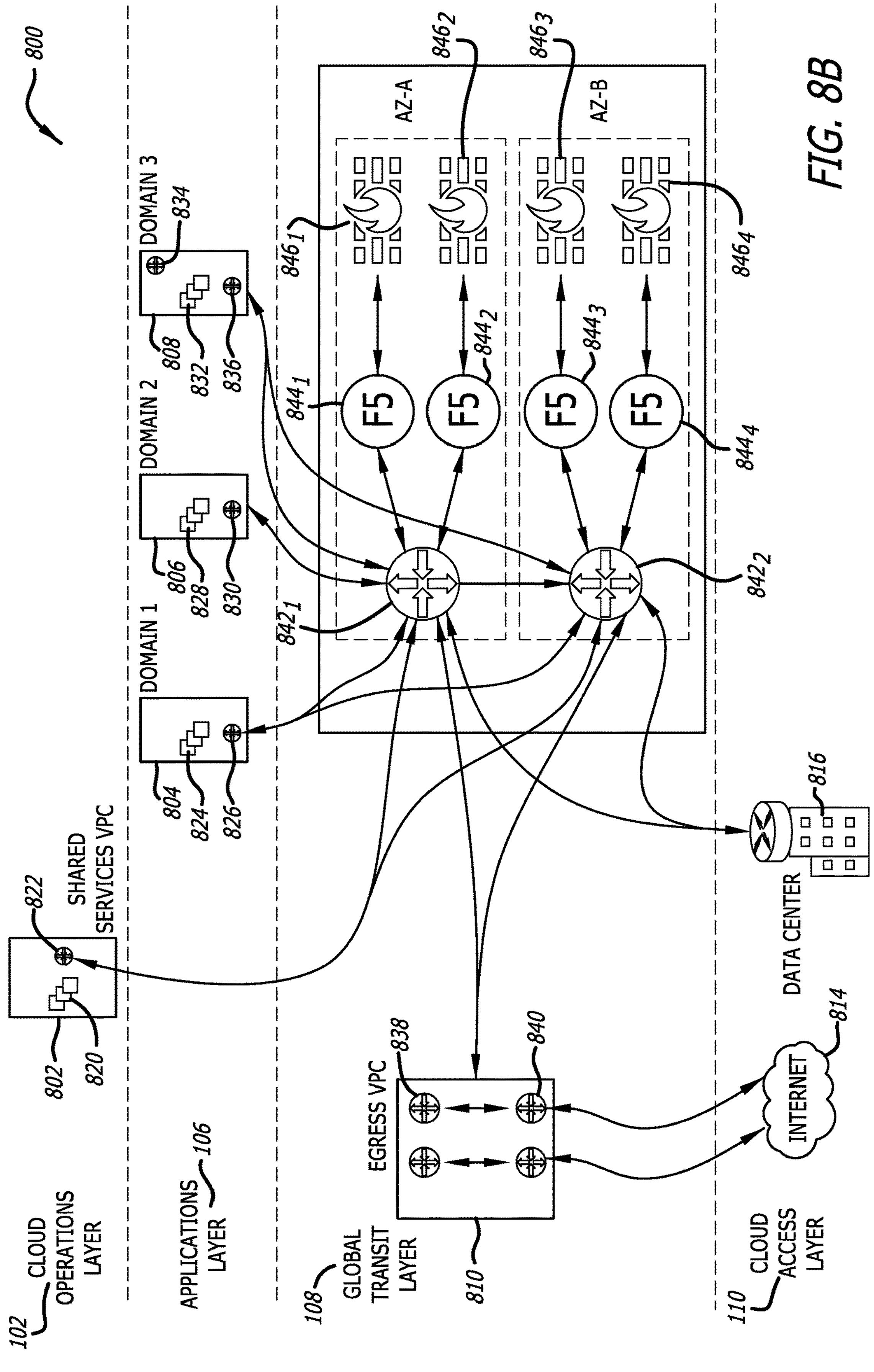

800
102
CLOUD OPERATIONS LAYER
APPLICATIONS LAYER
106
108
GLOBAL TRANSIT LAYER
110
CLOUD ACCESS LAYER
802
820
822
SHARED SERVICES VPC
804
824
826
DOMAIN 1
806
828
830
DOMAIN 2
808
832
836
834
DOMAIN 3
EGRESS VPC
838
840
810
INTERNET
814
DATA CENTER
816
AZ-A
AZ-B
842_1
842_2
844_1
844_2
844_3
844_4
F5
F5
F5
F5
846_1
846_2
846_3
846_4

FIG. 8B

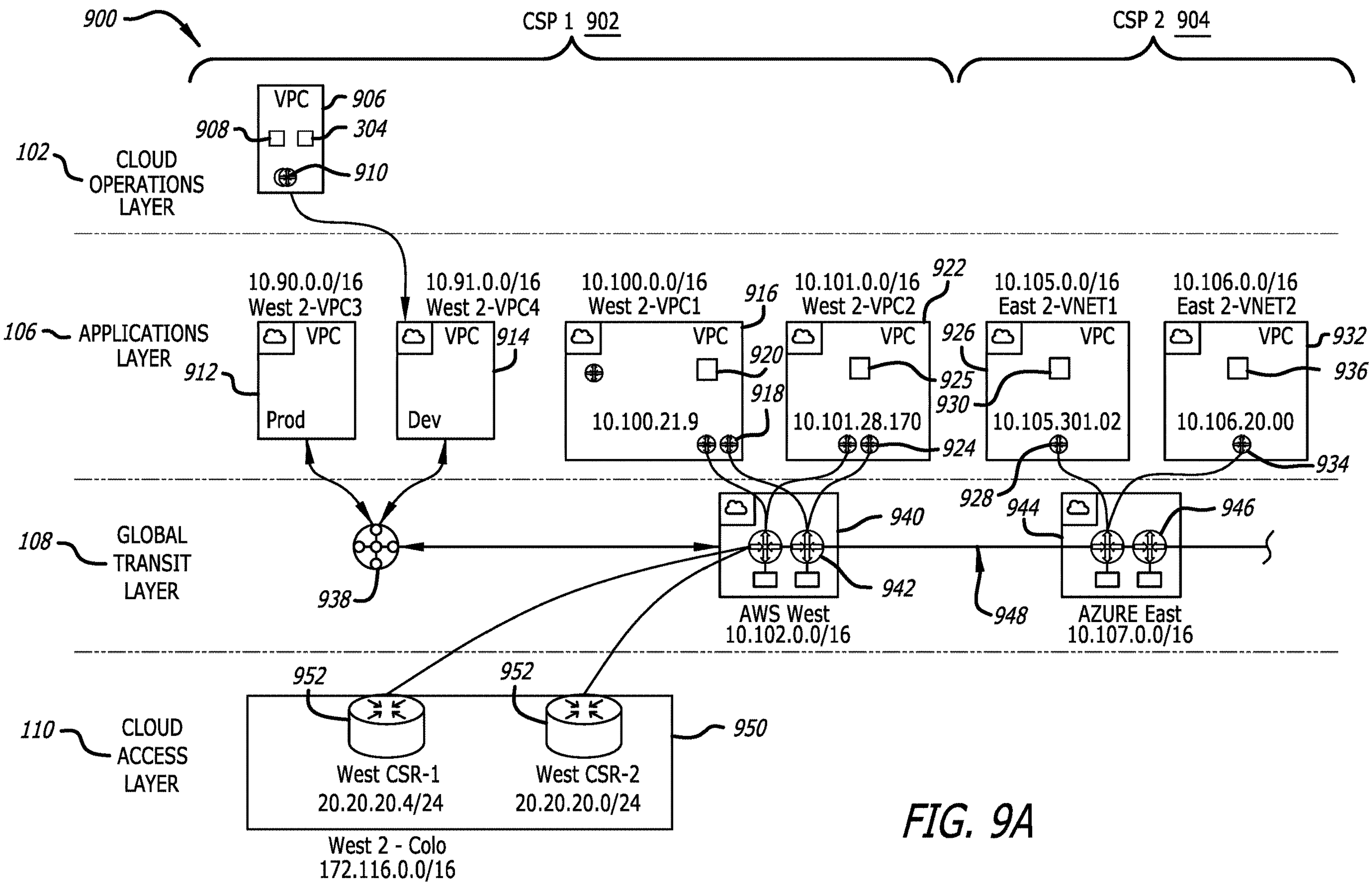
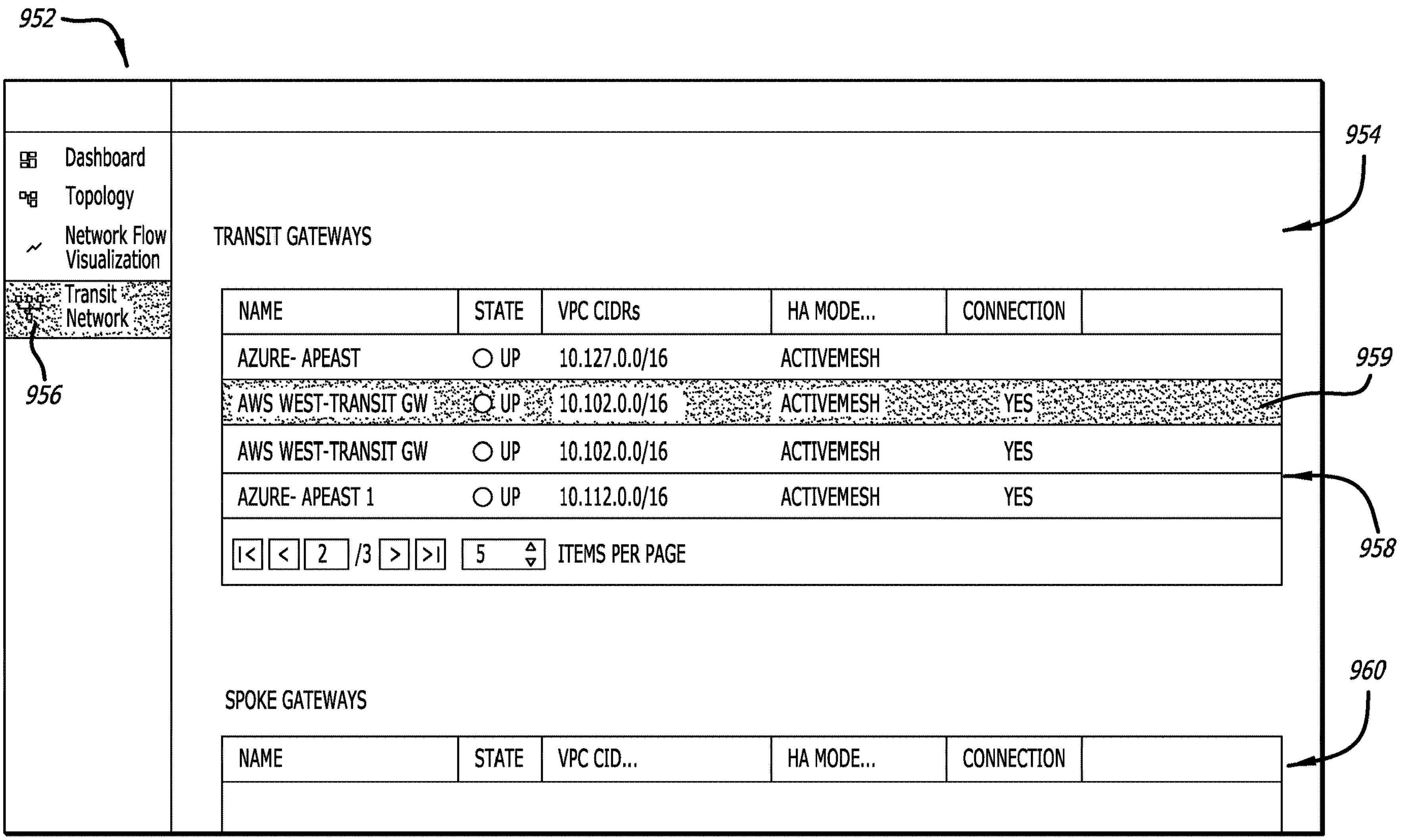

900
CSP 1 902
CSP 2 904
102
CLOUD OPERATIONS LAYER
VPC
906
908
304
910
106
APPLICATIONS LAYER
912
10.90.0.0/16
West 2-VPC3
VPC
Prod
10.91.0.0/16
West 2-VPC4
VPC
914
Dev
10.100.0.0/16
West 2-VPC1
916
VPC
920
918
10.100.21.9
10.101.0.0/16
West 2-VPC2
922
VPC
925
10.101.28.170
924
10.105.0.0/16
East 2-VNET1
926
VPC
930
10.105.301.02
928
10.106.0.0/16
East 2-VNET2
VPC
932
936
10.106.20.00
934
108
GLOBAL TRANSIT LAYER
938
940
942
AWS West
10.102.0.0/16
948
944
946
AZURE East
10.107.0.0/16
110
CLOUD ACCESS LAYER
952
952
950
West CSR-1
20.20.20.4/24
West CSR-2
20.20.20.0/24
West 2 - Colo
172.116.0.0/16

FIG. 9A



TRANSIT GATEWAYS

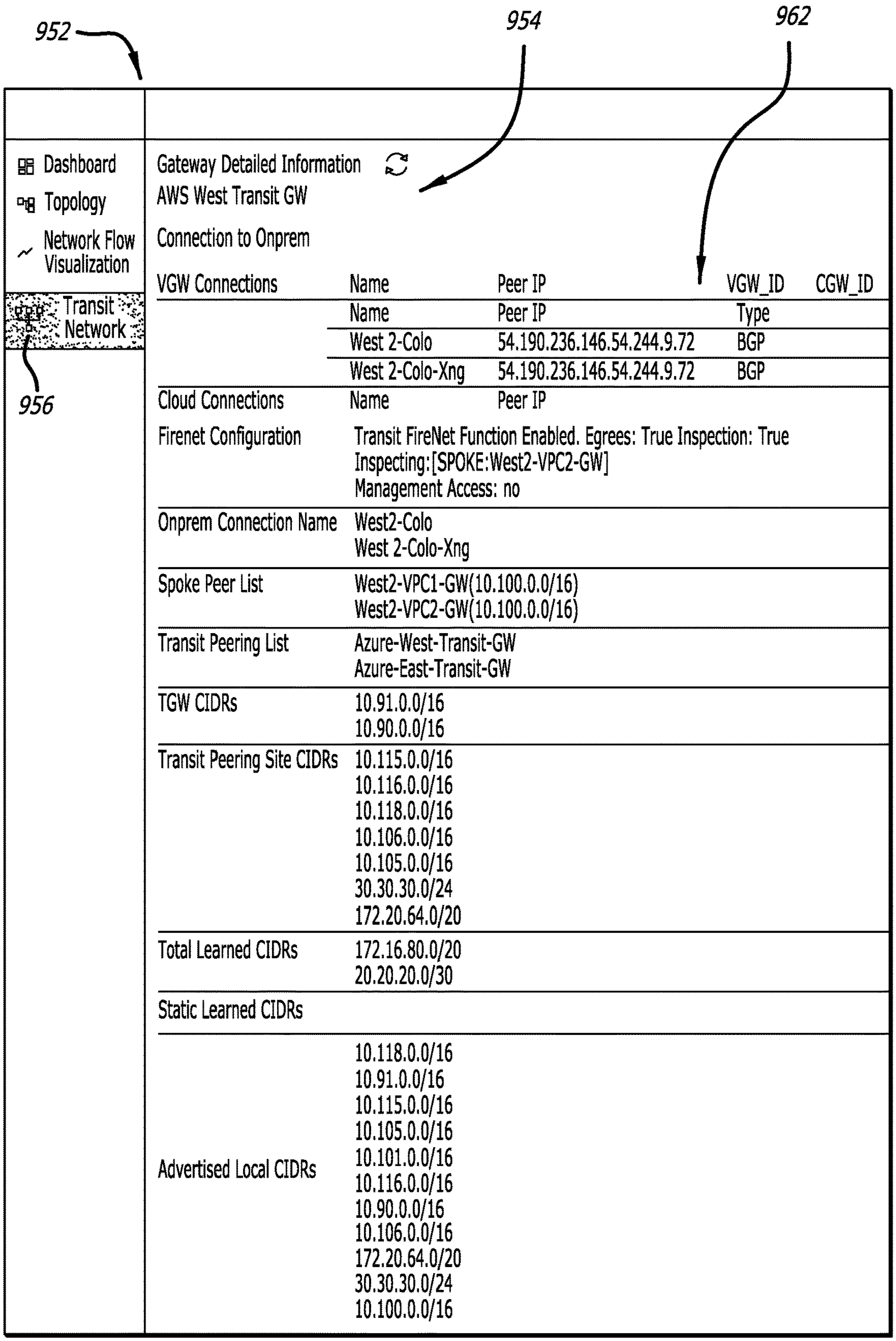
NAME	STATE	VPC CIDRs	HA MODE...	CONNECTION	
AZURE- APEAST	○ UP	10.127.0.0/16	ACTIVEMESH		
AWS WEST-TRANSIT GW	○ UP	10.102.0.0/16	ACTIVEMESH	YES	
AWS WEST-TRANSIT GW	○ UP	10.102.0.0/16	ACTIVEMESH	YES	
AZURE- APEAST 1	○ UP	10.112.0.0/16	ACTIVEMESH	YES	

|< < 2 /3 > >| 5 ▲▼ ITEMS PER PAGE

SPOKE GATEWAYS

NAME	STATE	VPC CID...	HA MODE...	CONNECTION	

FIG. 9B



Gateway Detailed Information
AWS West Transit GW

Connection to Onprem

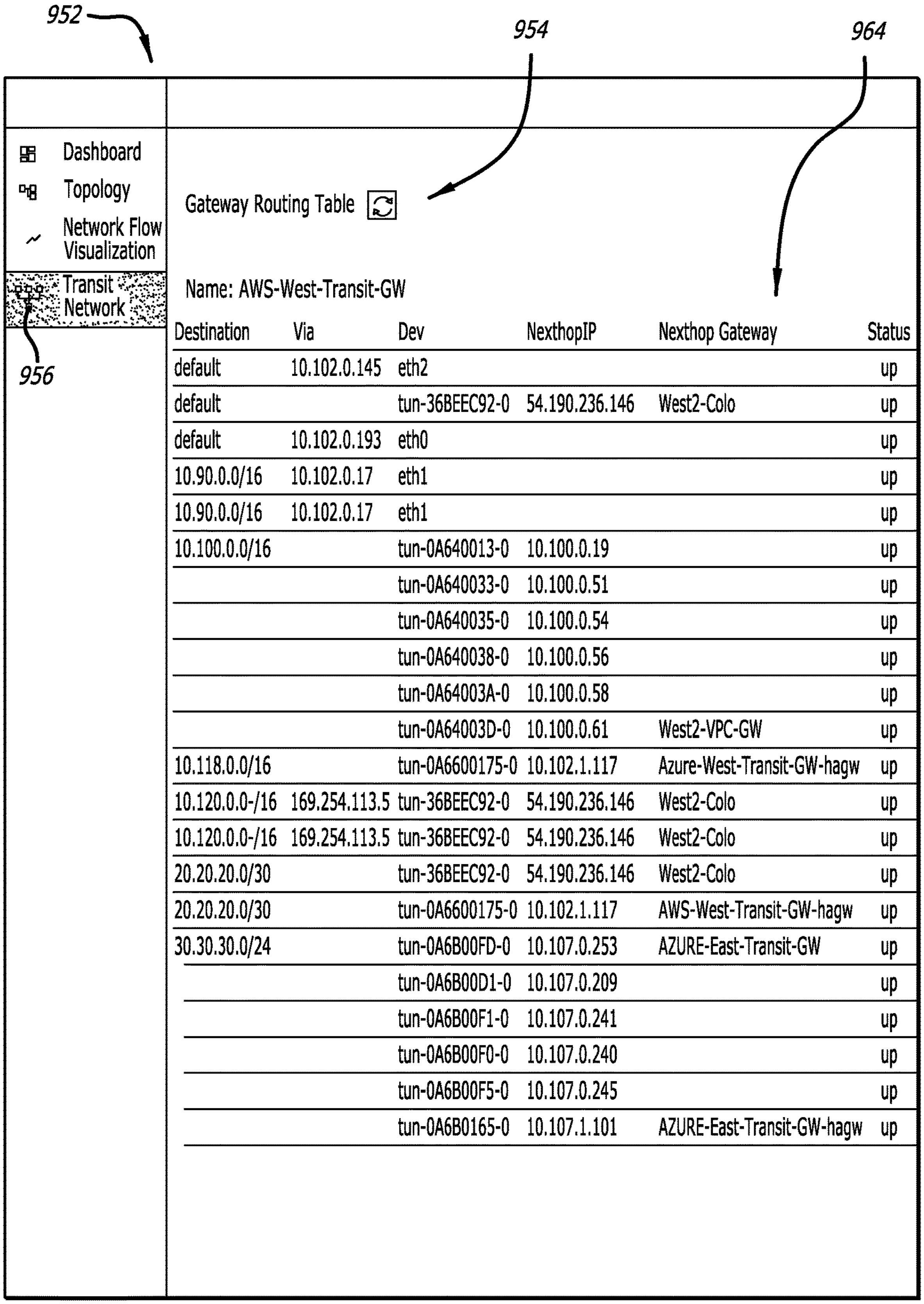
VGW Connections	Name	Peer IP	VGW_ID	CGW_ID
	Name	Peer IP	Type	
	West 2-Colo	54.190.236.146.54.244.9.72	BGP	
	West 2-Colo-Xng	54.190.236.146.54.244.9.72	BGP	
Cloud Connections	Name	Peer IP		

Firenet Configuration	Transit FireNet Function Enabled. Egrees: True Inspection: True Inspecting:[SPOKE:West2-VPC2-GW] Management Access: no
Onprem Connection Name	West2-Colo West 2-Colo-Xng

Spoke Peer List	West2-VPC1-GW(10.100.0.0/16)
	West2-VPC2-GW(10.100.0.0/16)

Transit Peering List	Azure-West-Transit-GW Azure-East-Transit-GW
TGW CIDRs	10.91.0.0/16 10.90.0.0/16
Transit Peering Site CIDRs	10.115.0.0/16 10.116.0.0/16 10.118.0.0/16 10.106.0.0/16 10.105.0.0/16 30.30.30.0/24 172.20.64.0/20
Total Learned CIDRs	172.16.80.0/20 20.20.20.0/30
Static Learned CIDRs	
Advertised Local CIDRs	10.118.0.0/16 10.91.0.0/16 10.115.0.0/16 10.105.0.0/16 10.101.0.0/16 10.116.0.0/16 10.90.0.0/16 10.106.0.0/16 172.20.64.0/20 30.30.30.0/24 10.100.0.0/16

FIG. 9C



Gateway Routing Table

Name: AWS-West-Transit-GW

Destination	Via	Dev	NexthopIP	Nexthop Gateway	Status
default	10.102.0.145	eth2			up
default		tun-36BEEC92-0	54.190.236.146	West2-Colo	up
default	10.102.0.193	eth0			up
10.90.0.0/16	10.102.0.17	eth1			up
10.90.0.0/16	10.102.0.17	eth1			up
10.100.0.0/16		tun-0A640013-0	10.100.0.19		up
		tun-0A640033-0	10.100.0.51		up
		tun-0A640035-0	10.100.0.54		up
		tun-0A640038-0	10.100.0.56		up
		tun-0A64003A-0	10.100.0.58		up
		tun-0A64003D-0	10.100.0.61	West2-VPC-GW	up
10.118.0.0/16		tun-0A6600175-0	10.102.1.117	Azure-West-Transit-GW-hagw	up
10.120.0.0-/16	169.254.113.5	tun-36BEEC92-0	54.190.236.146	West2-Colo	up
10.120.0.0-/16	169.254.113.5	tun-36BEEC92-0	54.190.236.146	West2-Colo	up
20.20.20.0/30		tun-36BEEC92-0	54.190.236.146	West2-Colo	up
20.20.20.0/30		tun-0A6600175-0	10.102.1.117	AWS-West-Transit-GW-hagw	up
30.30.30.0/24		tun-0A6B00FD-0	10.107.0.253	AZURE-East-Transit-GW	up
		tun-0A6B00D1-0	10.107.0.209		up
		tun-0A6B00F1-0	10.107.0.241		up
		tun-0A6B00F0-0	10.107.0.240		up
		tun-0A6B00F5-0	10.107.0.245		up
		tun-0A6B0165-0	10.107.1.101	AZURE-East-Transit-GW-hagw	up

FIG. 9D

SYSTEMS AND METHODS FOR IMPLEMENTING A REPEATABLE NETWORK ARCHITECTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority on U.S. Provisional Application No. 63/038,701, filed Jun. 12, 2020, and on U.S. Provisional Application No. 63/190,746, filed May 19, 2021, the entire contents of each are incorporated by reference herein.

FIELD

Embodiments of the disclosure relate to the field of network architectures. More specifically, one embodiment of the disclosure pertains to a network architecture that may be repeated for use within multiple regions within a cloud computing environment provided by a single cloud provider or within multiple cloud computing environments provided by multiple cloud service providers. Further embodiments disclose systems and methods of implementing the repeatable architecture with a network architecture platform.

GENERAL BACKGROUND

As companies transition from primarily hosting computing resources locally, e.g., hosting server and storage devices at on-premise data centers, to primarily utilizing such resources of a commercial provider to perform computing workloads remotely via the internet, e.g., utilizing cloud computing resources, an emphasis has been placed on the security of data and processing hosted within the cloud computing resources ("cloud computing"). Cloud computing resources provided by a commercial provider are often referred to as a "public cloud." Portions of the public cloud, which may be referred to as virtual private clouds (VPCs) or virtual private networks (VNETs), may be provisioned for individuals or individual companies. As both VPCs and VNETs are known, the terms will be used interchangeably unless otherwise stated with a particular embodiment. For purposes of clarity, the term VPC will be used generally throughout the disclosure.

Cloud computing provides Infrastructure as a Service (IaaS), where resources are provided as part of a public cloud network and made accessible as a service to organizations as well as the persons associated with these organizations such as administrators, employees, contractors, or the like (hereinafter, "users"). One of these services allows users to run software components (e.g., software instances such as virtual servers) within the public cloud network. Hence, the migration of software functionality into the public cloud network has led to greater usage of virtual private networks deployed within the public cloud network.

However, as ubiquitous as cloud computing has become recently, typical methods for building a cloud computing environment leave much to be desired. As is often the case, a user may migrate a portion of their computing needs (storage or processing) to cloud computing. However, such is done without forethought as to how future migration may occur. Further, upon subsequently migrating a second portion of their computing needs to cloud computing either utilizing resources of a single cloud service provider or those of multiple cloud service providers, there is often a disconnect between the first migration and second migration.

More specifically, network engineers or administrators tasked with migrating computing needs to cloud computing often have to do duplicative work between a first migration and subsequent migrations. For instance, scripts or automations developed during the first migration typically need to be re-developed during the second migration, especially when the first and second migrations utilize different cloud service providers.

Further, when utilizing multiple cloud service providers in the fashion described above, the network engineer or administrator has created multiple cloud computing environments that are distinct and wholly separate from one another. Specifically, when constructs deployed during the first migration are operating on computing resources of a first cloud service provider and constructs deployed during the second migration are operating on computing resources of a second cloud service provider, the two sets of constructs are isolated from one another and are unable to communicate.

Additionally, such isolation results in a lack of overall visibility, meaning that the network engineers or administrator cannot obtain network traffic analysis (e.g., status of constructs, metrics or statistics of network traffic flow, etc.) across all of the users' computing needs being handled in the cloud. Specifically, the different cloud service providers each provide visibility to computing needs handled on their own computing resources.

As one example, when an organization utilizes cloud computing resources provided by both GOOGLE® and AMAZON®, a network administrator from the organization cannot obtain visibility of the network traffic or the deployed constructs associated with the clouds provided by both cloud services providers in a single location. Instead, the network administrator is only capable of obtaining visibility of network traffic propagating through and constructs deployed in the GOOGLE® cloud via an interface provided by GOOGLE® and the same for the AMAZON® cloud. Additionally, the network administrator is unable to deploy or otherwise control constructs in both clouds from a single interface.

Thus, what is needed is a network architecture that is repeatable across regions of cloud computing resources provided by a single cloud service provider and also repeatable across cloud computing resources provided by multiple cloud service provider. Additional needs include such a network architecture providing control over and visibility of all constructs and connections therebetween regardless of the cloud in which the constructs are deployed.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the disclosure are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

FIG. **1** is a diagram of an exemplary embodiment of a repeatable network architecture in accordance with some embodiments;

FIG. **2** is a diagram of an example embodiment of the repeatable network architecture utilized to form a client's cloud computing environment that includes multiple cloud computing environments provided by multiple cloud service providers accordance with some embodiments;

FIG. **3** is an illustration of an example embodiment of a network architecture platform that may be utilized to implement the repeatable network architecture of FIG. **1** in accordance with some embodiments;

FIG. **4** is a diagram of the network architecture platform of FIG. **3** provided as an overlay to the client's cloud computing environment of FIG. **2** in accordance with some embodiments;

FIG. **5** is an illustration of an example cloud computing environment implemented with the network architecture platform of FIG. **3** in accordance with some embodiments;

FIG. **6**A is an illustration of a first portion of an example cloud computing environment implemented with the network architecture platform of FIG. **3** including an applications layer and a network layer in accordance with some embodiments;

FIG. **6**B is an illustration of a second portion of the example cloud computing environment of FIG. **6**A implemented with the network architecture platform of FIG. **3** including the applications layer, the network layer and a cloud access layer in accordance with some embodiments;

FIGS. **7**A-**7**B are illustrations of a first portion of an example cloud computing environment implemented with the network architecture platform of FIG. **3** including an applications layer and a network layer each of FIG. **1** in accordance with some embodiments;

FIGS. **8**A-**8**B are illustrations of example cloud computing environments implemented with the network architecture platform of FIG. **3** including service constructs in accordance with some embodiments;

FIG. **9**A is an illustration of an example cloud computing environment implemented with the network architecture platform of FIG. **3** including an applications layer and a network layer each of FIG. **1** in accordance with some embodiments; and

FIGS. **9**B-**9**D are illustrations of example visualizations of a transit network visualization generated by the visibility logic **304** in accordance with some embodiments.

DETAILED DESCRIPTION

Embodiments of the disclosure are directed to a repeatable network architecture and methods of implementing the network architecture to build a cloud computing environment. The repeatable network architecture (architecture) includes a plurality of layers, wherein a one or more constructs are deployed within each of the layers. In some embodiments, the layers include a cloud operations layer, a cloud core layer (including an applications layer and a global transit layer), and a cloud access layer. The architecture is configured such that the constructs deployed therein are each configured to perform certain operations where the combination of operations performed by the constructs across the multiple layers forms an intelligent architecture design.

Further, the architecture may be instructive for building a cloud computing system that spans multiple regions within a cloud provided by a single cloud service provider (CSP) as well as a cloud computing system that spans multiple clouds each provided by a different CSP. Specifically, many of the constructs deployed in each layer may be repeated in a corresponding layer in a separate region or cloud.

Some embodiments of the disclosure provide a network architecture platform (platform) that may be utilized to implement the architecture, where the platform is comprised of certain constructs such as a controller, visibility logic and a set of one or more gateways. In some embodiments, a cloud computing environment may be built by implementing the architecture such that the cloud computing environment includes constructs in at least the cloud operations layer, an applications layer and a global transit layer, and where deployment of constructs within a cloud access layer is optional. In such an embodiment, a controller and visibility logic may be deployed within a virtual private cloud (VPC) that is itself deployed within a first cloud, where the controller and visibility logic are disposed within the cloud operations layer. Additionally, the cloud computing environment may include a plurality of spoke VPCs that are deployed across multiple clouds, where the controller is configured to deploy the spoke VPCs and where the controller is further configured to deploy a spoke gateway in one or more of the spoke VPCs. The spoke VPCs may all be disposed in the applications layer.

The cloud computing environment may also include a plurality of transit VPCs each having deployed therein a transit gateway, where the controller is configured to deploy the transit VPCs and the transit gateways. Each region each cloud may have deployed therein a transit VPC, where the transit VPCs are all disposed within the global transit layer. The controller may be configured to establish a communicative coupling between a spoke VPC and a transit VPC (e.g., each located within the same region of the same cloud) and between transit VPCs. As a result, the spoke VPCs are indirectly communicatively coupled to each other via the transit VPCs regardless of the region or cloud in which each spoke VPC is deployed.

Additionally, the controller may be further configured to establish communicative couplings between the transit VPCs and network devices such as laptops, mobile phones, data centers and/or the internet. In some instances, gateways may be deployed on (or at) the network devices, where such are considered to be deployed within the cloud access layer.

I. Terminology

In the following description, certain terminology is used to describe features of the invention. In certain situations, the term "logic" is representative of hardware, firmware, and/or software that is configured to perform one or more functions. As hardware, the logic may include circuitry having data processing or storage functionality. Examples of such circuitry may include, but are not limited or restricted to a microprocessor, one or more processor cores, a programmable gate array, a microcontroller, an application specific integrated circuit, wireless receiver, transmitter and/or transceiver circuitry, semiconductor memory, or combinatorial logic.

Alternatively, or in combination with the hardware circuitry described above, the logic may be software in the form of one or more software modules. The software module(s) may include an executable application, an application programming interface (API), a subroutine, a function, a procedure, an applet, a servlet, a routine, source code, a shared library/dynamic load library, or one or more instructions. The software module(s) may be stored in any type of a suitable non-transitory storage medium, or transitory storage medium (e.g., electrical, optical, acoustical or other form of propagated signals such as carrier waves, infrared signals, or digital signals). Examples of non-transitory storage medium may include, but are not limited or restricted to a programmable circuit; a semiconductor memory; non-persistent storage such as volatile memory (e.g., any type of random access memory "RAM"); persistent storage such as non-volatile memory (e.g., read-only memory "ROM", power-backed RAM, flash memory, phase-change memory, etc.), a solid-state drive, hard disk drive, an optical disc drive, or a portable memory device. As firmware, the executable code may be stored in persistent storage.

The term "computerized" generally represents that any corresponding operations are conducted by hardware in combination with software and/or firmware.

The term "construct" may be construed as a virtual or physical logic directed to a particular functionality such as a controller, a gateway, virtual private cloud network (VPC), sub-network, or the like. For instance, as an illustrative example, the construct may correspond to virtual logic in the form of software (e.g., a virtual machine), which may assign a device-specific address (e.g., a Media Access Control "MAC" address) and/or an IP address within an IP address range supported by to a particular IP subnet. Alternatively, in some embodiments, the construct may correspond to physical logic, such as an electronic device that is communicatively coupled to the network and assigned the MAC and/or IP address(es). Examples of electronic devices may include, but are not limited or restricted to a personal computer (e.g., desktop, laptop, tablet or netbook), a mobile phone, a standalone appliance, a sensor, a server, or an information routing device (e.g., a router, bridge router ("brouter"), etc.). It is contemplated that each construct may constitute at least logic residing as part of a public network, although certain constructs may be deployed as part of an "on-premises" ("on-prem" or local) network.

The term "virtual private cloud network (VPC)" may refer to an on-demand, configurable pool of shared resources, which are allocated within a cloud computing platform and provide a certain level of isolation between the different organizations or other entities (hereinafter, "users") using the resources.

The term "transit VPC" may refer to a VPC that is configured, in accordance with one embodiment, to connect multiple VPCs, where the VPCs may be logically isolated and/or virtually located on data centers that may be geographically disparate. A transit VPC serves as a global network transit center that operates as a connection point for spoke VPC-to-spoke VPC communication (e.g., propagation of network traffic having a source IP address in a first spoke VPC and a destination IP address in a second spoke VPC), spoke VPC-to-data center communication (e.g., propagation of network traffic having a source IP address in a first spoke VPC and a destination IP address at a data center), and may also route network traffic to other transit VPCs (e.g., propagation of network traffic having a source IP address in a first spoke VPC connected to a first transit VPC and a destination IP address in a second spoke VPC connected to a second transit VPC), which may then continue propagation of the network traffic.

The term "gateway" may be construed as virtual or physical logic. For instance, as an illustrative example, the gateway may correspond to virtual logic in the form of a software component, such as a virtual machine (VM)-based data routing component that is assigned a Private IP address within an IP address range associated with a VPC including the gateway. The gateway allows Cloud Service Providers (CSPs) and enterprises to enable datacenter and cloud network traffic routing between virtual and physical networks, including a public network (e.g., Internet). Alternatively, in some embodiments, the gateway may correspond to physical logic, such as an electronic device that is communicatively coupled to the network and assigned the hardware (MAC) address and an IP address.

Hence, multiple gateways may be deployed in a VPC and these gateways may be configured to control the flow of traffic from software instances of the VPC to one or more remote sites including computing devices that may process data received from the software instances. Having similar architectures, the gateways may be identified differently based on their location/operability within a public cloud network platform. The "spoke" gateways are configured to interact with targeted instances while "transit" gateways are configured to further assist in the propagation of data traffic (e.g., one or more messages) directed to a spoke gateway within a spoke VPC or a computing device within an on-premises network. Stated differently, a spoke gateway interacts with a user instance while a transit gateway is configured as a hub that routes network traffic. Typically, a transit gateway instance requires more memory and supports additional configurations as compared to a spoke gateway.

The term "controller" may refer to a software instance deployed within a cloud computing environment (e.g., resources of a public cloud network) that manages operability of certain aspects of one or more cloud computing environments spanning across different public cloud networks (multi-cloud network). For instance, a controller may be configured to collect information pertaining to each VPC and/or each gateway and configures one or more routing tables associated with one or more VPCs and/or gateways spanning a multi-cloud network to establish communication links (e.g., logical connections) between different sources and destinations. These sources and/or destinations may include, but are not restricted or limited to on-premises computing devices, gateways or other types of cloud resources.

The term "cloud computing services" may generally refer to computer system resources such as data storage ("cloud storage") and computing resources that is utilized without direct, active management by a user. Cloud computing services may generally be used herein to refer to data centers available to users that are accessible by the internet. In some instances, cloud computing services may also incorporate software and other logic that are accessible by users to have certain tasks executed on the computing resources. The term "cloud computing services" may be used interchangeably with the terms, "cloud" and "cloud services." A cloud may be public (accessible to all users) or private (accessible to a subset of users that provide the required authentication information). Additionally, the term "cloud computing environment" may generally refer to data storage and computing resources of a cloud and all constructs deployed (launched) and configured for processing on the computing resources.

The term "message" generally refers to information in a prescribed format and transmitted in accordance with a suitable delivery protocol. Hence, each message may be in the form of one or more packets, frames, or any other series of bits having the prescribed format.

The term "network device" may be construed as any electronic computing system with the capability of processing data and connecting to a network. Such a network may be a public network such as the internet or a private network such as a wireless data telecommunication network, wide area network, a type of local area network (LAN), or a combination of networks. Examples of a network device may include, but are not limited or restricted to, an endpoint device (e.g., a laptop, a mobile phone, a tablet, a computer, etc.), a standalone appliance, a server, a router or other intermediary communication device, a firewall, etc.

The term "link" may be generally construed as a physical or logical communication path between two or more constructs. For instance, as a physical communication path, wired and/or wireless interconnects in the form of electrical wiring, optical fiber, cable, bus trace, or a wireless channel using infrared, radio frequency (RF), may be used. A logical communication path includes any communication scheme that enables information to be exchanged between multiple constructs.

The term "repeatable" may refer the ability of one or more aspects of a cloud computing environment to be (i) ported from a first region of a cloud service provider to a second region of the cloud service provider, (ii) duplicated from deployment in a first region of a cloud service provider to deployment in a second region of the cloud service provider, (iii) ported from cloud computing services of a first cloud service provider to cloud computing services of a second cloud service provider, and/or (iv) duplicated from deployment in cloud computing services of a first cloud service provider to deployment in cloud computing services of a second cloud service provider. However, the specific configuration of constructs deployed within a single region or cloud (e.g., number of constructs) is not required to be replicated.

Finally, the terms "or" and "and/or" as used herein are to be interpreted as inclusive or meaning any one or any combination. As an example, "A, B or C" or "A, B and/or C" mean "any of the following: A; B; C; A and B; A and C; B and C; A, B and C." An exception to this definition will occur only when a combination of elements, functions, steps or acts are in some way inherently mutually exclusive.

As this invention is susceptible to embodiments of many different forms, it is intended that the present disclosure is to be considered as an example of the principles of the invention and not intended to limit the invention to the specific embodiments shown and described.

II. Repeatable Network Architecture

Referring now to FIG. **1**, a diagram of an exemplary embodiment of a repeatable network architecture is shown in accordance with some embodiments. As illustrated in FIG. **1**, the repeatable network architecture includes a plurality of layers, such that certain networking constructs are included in a particular layer. The layering of the constructs in the manner set forth herein enables a network administrator or other user developing a cloud computing environment to do so intelligently and efficiently. As mentioned above, developing a cloud computing environment without a layered approach as disclosed herein often leads to haphazard placement of constructs, development of scripts and connections between constructs that are not repeatable.

Thus, the repeatable network architecture **100** (architecture **100**) of FIG. **1** includes a cloud operations layer **102**, a cloud core layer **104** that includes an applications layer **106** and a network layer **108**, and a cloud access layer **110**. In some embodiments, within the framework of the architecture **100**, the cloud operations layer **102** includes constructs that perform functionalities of automation, orchestration, visibility and control, logging of network traffic and corresponding events (latency, routing, etc.), network traffic flow analysis, troubleshooting, network management, network traffic packet capture, multi-account access, monitoring, capacity planning and alert generation.

Typically, the constructs deployed within the cloud operations layer **102** include access to network administrators or others (collectively, network administrators) through a graphical user interface (GUI). For instance, a GUI may be accessed and displayed via a web browser and/or via a dedicated software application processing on a network device (e.g., a tablet, laptop, mobile phone, etc.). One of more of the constructs deployed within the cloud operations layer **102** may obtain data pertaining to constructs deployed in other layers and present such data to the network administrator, which may include status/state of constructs or connections therebetween, network traffic flows, etc. Additionally, the GUI may be configured to receive user input that results in alterations to constructs deployed in other layers, such as a change of state, deployment of additional constructs, establishment of connections between constructs (at times, connections may be referred to as attachments), etc.

The cloud core layer **104** may be divided into sub-layers, namely, the applications layer **106** and the network layer **108**. The constructs deployed therein, in combination, provide the functionalities of access routing, aggregation routing, core routing, level 4 firewall (L4FW) deployment, next generation firewall (NGFW) deployment, load balancing, internet access, workload processing, storage, software as a service (Saas), multi-region cloud services deployment, multi-cloud services deployment, encryption, and wide area network (WAN) optimization. The constructs deployed within the cloud core layer **104** may be managed by one or more constructs deployed within the cloud operations layer **102**. For example, and as will be discussed in detail below, a controller may be deployed in the cloud operations layer **102** that deploys or launches constructs within the cloud core layer **104** and subsequently manages those constructs, where management thereof may refer to establishing connections between constructs, monitoring the state or status of each construct and connection, monitoring network traffic flow among the constructs and even establishing routes of network traffic by programming the constructs with routing tables.

The cloud access layer **110** may include constructs that provide network devices with access to constructs within the cloud core layer **104**. Additionally, in some embodiments, the cloud access layer **110** may be understood to include the connections between constructs deployed within the cloud core **104** (e.g., the network layer **108**) and network devices. Examples of network devices that access the constructs of the cloud core layer **104** include, but are not limited or restricted to, data centers (often times, "on-premise" or "on-prem" data centers), branches (e.g., corporate offices), network devices of users (e.g., laptops, desktop computers, tablets, mobile phones, internet of things (IoT) devices, etc.), etc.

In embodiments, the connections between the network devices of the cloud access layer **110** and constructs of the cloud core layer **104** may include virtual private networks (VPNs), software-defined wide area network (SD-WANs) connections, multi-protocol label switching (MPLS), broadband cellular connections (e.g., 4G, 5G), GOOGLE® Interconnect, etc. Additionally, the cloud access layer **110** may include deployment of firewalls, encryption and/or inspection of network traffic, and WAN optimization.

Referring now to FIG. **2**, a diagram of an example embodiment of the repeatable network architecture utilized to form a client's cloud computing environment **200** that includes multiple clouds provided by multiple cloud service providers is shown in accordance with some embodiments. The diagram of FIG. **2** illustrates the repeatability of the architecture **100** implemented in creating the multi-cloud networking environment **200** with three cloud service providers (CSPs), where clouds provided by each CSP are illustrated as clouds **202**, **204** and **206**. In particular, constructs are deployed in each of the cloud operations layers **102**, the cloud core layer **104** and the cloud access layer **110** thereby creating a portion of the cloud environment **200** within each of the cloud **202** provided by a first CSP, the cloud **204** provided by a second CSP and the cloud **206** provided by a third CSP. Examples of constructs that are configured for deployment within each of the layers **102**, **104** and **110** are discussed below.

FIG. **2** illustrates that a portion of the architecture **100** may be repeated for multiple regions within cloud services provided by a single CSP. For example, the cloud **202** provided by a first CSP include regions **2081-2082**, where the constructs within the cloud core layer **104** may be repeated in each region and where the constructs with the cloud operations layer **102** and the cloud access layer **110** are used by the constructs in both regions. It should be understood that the layered approach of the architecture **100** leads to repetition of the layers and the constructs which are or may be deployed or launched within each layer. The repetition of the architecture **100** does not require the repetition of the same configuration of constructs deployed and connections established in each deployment. Thus, as shown in at least FIGS. **5**-**6**B, the layered approach of the architecture **100** is repeatedly in developing a multi-cloud network architecture that spans multiple clouds and/or multiple regions within a single cloud.

III. Network Architecture Platform

Referring to FIG. **3**, an illustration of an example embodiment of a network architecture platform that may be utilized to implement the repeatable network architecture of FIG. **1** is shown in accordance with some embodiments. The network architecture platform (platform) **300** is one embodiment of a network architecture platform that may be utilized to implement the architecture **100**. As shown, the platform **300** includes a controller **302** and visibility logic **304**, which are configured to be deployed and operate within the cloud operations layer **102**, and one or more gateways **306** that are configured to be deployed and operate in the cloud core layer **104**.

In one embodiment, the visibility logic **304** may query the controller **302** for data indicating a status and metadata of each construct managed by the controller **302** and also receive network data from one or more gateways **306** (spoke or transit). The visibility logic **304** includes logic that, upon execution by one or more processors (e.g., being part of the cloud computing resources), generates various visualizations that are a combination of the construct status and metadata (collectively "construct metadata") and the network data. The visualizations may be interactive and provided to users such as network administrators, information technology (IT) professionals, or the like. Additionally, the visualizations may be configured to receive user input, which causes the logic of the visibility logic **304** ("topology system logic") to alter the visualizations. As discussed below and illustrated in the accompanying drawings, the visualizations may include, but are not limited or restricted to, a dashboard view providing overall status and health of the network as well as specific network parameters; a dynamic topology mapping that provides a visual rendering of each construct and links that identify communications between the constructs; and a network flow visualization providing various illustrations detailing how network traffic is flowing (or has flowed) through a cloud computing environment managed by the controller **302**. Each of the visualizations may provide data spanning a multi-cloud network. Further detail regarding the visibility logic **304** may be found in U.S. patent application Ser. No. 17/006,657, titled "System and Method for Determination of Network Operation Metrics and Generation of Network Operation Metrics Visualizations," filed Aug. 28, 2020, the entire contents of which are incorporated herein by reference.

In some embodiments, one or more gateways **306** may also be configured to be deployed and operate in the cloud access layer **110**, for example, at a datacenter. The platform **300** may be configured to deploy (or launch) and monitor constructs **308** provided directly by a cloud service provider (referred to as native constructs), wherein the deployment and monitoring may be accomplished through the use of one or more APIs. In some embodiments, the controller **302** and the gateways **306** are deployed as a software instance operating on cloud services provided by one or more CSPs. As used herein, the term "construct" may generally refer to a controller, gateways, virtual private clouds (VPCs) (or the equivalent based on CSP, which may include MICROSOFT® AZURE virtual networks (VNETs), GOOGLE® CLOUD PLATFORM VPCs, AMAZON WEB SERVICES (AWS)® VPCs, ORACLE CLOUD INFRASTRUCTURE (OCI) virtual cloud networks (VCNs), etc.), firewalls, etc.

In some embodiments, a single instance of the controller **302** may be deployed in a client's cloud computing environment, where the single instance operates on computing resources of a single CSP. However, the controller **302** is configured to access the computing resources of all CSPs that are to provide such for the client's computing environment.

As an illustrative example, a client's cloud computing environment may consist of computing resources provided by three separate CSPs. In such an example, an instance of the controller **302** may be deployed within a cloud provided by a first CSP (first cloud) and, receive as user input, authentication credentials to access the clouds provided by the second and third CSPs (second and third clouds, respectively). As a result, the controller **302** that is deployed within the first cloud may deploy and monitor gateways **306** and native constructs **308** within the first cloud as well as the second and third clouds.

Referring to FIG. **4**, a diagram of the network architecture platform of FIG. **3** provided as an overlay to the client's cloud computing environment of FIG. **2** is shown in accordance with some embodiments. The diagram of FIG. **4** provides an abstract illustration of components of the platform **300** implemented in the appropriate layer. As seen, the controller **302** and the visibility logic **304** are deployed in the cloud operations layer **102** and gateways **304** are deployed in both of the global transit layer **108** of the cloud core layer **104** and the cloud access layer **110**.

As will be described in detail below, in implementing the architecture **100** to develop a cloud computing environment comprising clouds of multiple CSPs, an instance of the controller **302** and an instance of the visibility logic **304** may be deployed within a cloud of a first CSP, where the controller **302** is configured to access the clouds of each CSP within the cloud computing environment to deploy and monitor constructs therein. The controller **302** and the visibility logic **304** thereby form the cloud operations layer **102** of the architecture **100**.

The gateways **304** and the native constructs **306** deployed by the controller **302** as well as the connections established therebetween form the cloud core layer **104**. In some embodiments, as illustrated in at least FIGS. **5**-**6**B, the gateways **304** and the native constructs **306** may be deployed in clouds provided by multiple CSPs. Additionally, the controller **302** may deploy one or more gateways **304** within the cloud access layer **110**, e.g., at a remote datacenter.

IV. Implementation of the Repeatable Network Architecture using a Network Architecture Platform

Referring now to FIG. **5**, an illustration of an example cloud computing environment implemented with the network architecture platform of FIG. **3** is shown in accordance with some embodiments. The example cloud computing environment **500** (environment **500**) is developed by implementing the architecture **100** with the platform **300**, each discussed above. FIG. **5** illustrates the environment **500** with the layers of the architecture **100** overlayed thereon. Thus, FIG. **5** illustrates that the environment **500** includes a plurality of constructs deployed within the layers of the architecture **100**. Further, the example environment **500** spans multiple (three) clouds with the architecture **100** being repeated in each cloud, e.g., the same layering configuration is utilized in each cloud while the constructs deployed in each may differ.

In particular, the example environment **500** spans multiple clouds, e.g., a first cloud provided by a first CSP and a second cloud provided by a second CSP. Within the first cloud, a controller **502** and visibility logic **504** are deployed within the cloud operations layer **102**, and specifically, within the VPC **506**, which is labeled "shared services domain." As used herein, deployment of a construct such as a controller or visibility logic may occur within a virtual machine, where the term "virtual machine" may refer to a virtualized/emulation of a computer system. The term virtual machine (VM) may refer to a sandboxed virtual environment and be intended to include MICROSOFT AZURE® virtual machines, AMAZON ELASTIC COMPUTE CLOUD® (AMAZON EC2), GOOGLE CLOUD PLATFORM® compute engines, or the like. It is noted that not every instance of a virtual machine is illustrated in the drawings for purposes of clarity.

Returning to FIG. **5**, the first cloud (cloud **1**) further includes the VPC **508** that is deployed within the applications layer **106**, where the VPCs **508** represents a second domain (or secure partitioned area of the first cloud), labeled "domain **1**." A plurality of VPCs each including one or more VMs may be deployed or launched within domain **1**, where the network traffic entering and exiting the VPCs **508** is monitored by the controller **502**. Spoke gateways may be deployed within the VPCs **506**, **508** as well as **522**, **524** (discussed below) but are not shown for purposes of clarity.

Within the global transit layer **108**, the first cloud includes a gateway **510**, a VPC **512** labeled "firewall VPC" and a second VPC **514**. As shown, the firewall VPC **512** may include one or more gateways and one or more firewalls, where the firewall VPC **512** may be configured to inspect network traffic propagating through the first cloud. Further detail of the firewall VPC **512** may be found in U.S. patent application Ser. No. 17/216,601, titled "Systems and Methods for Load Balancing Network Traffic at Firewalls Deployed in a Cloud Computing Environment," filed Mar. 29, 2021, the entire contents of which are incorporated herein by reference.

As further illustrated, the gateway **510** is communicatively coupled to a datacenter **516** and the VPC **514** is communicatively coupled to branch offices **520**. The method of communicatively connecting these VPCs to network devices (optionally via a gateway instance deployed thereon) may be any of the connection methods referenced herein including MICROSOFT® AZURE Express Route, GOOGLE® Cloud Interconnect, Internet Protocol Security (IPsec) tunnels, etc. The VPC **514** is also shown as being communicatively coupled with branch offices **530** via a SD-WAN connection.

The second cloud (cloud **2**) includes two domains (domain **1** and domain **2**) within the applications layers **106**, where each domain may include one or more VNETs. The distinction between deployment of VPCs in the first cloud and VNETs in the second cloud indicates that the second cloud is provided by a second CSP different than a first CSP that is providing the first cloud. The VNET **526** is deployed within the global transit layer **108**, where the VNET **526** includes two high-availability gateways each with a corresponding firewall. The VNET **526** is communicatively coupled to the branch offices **530** via the SD-WAN connection **528**.

FIG. **5** illustrates that the spoke VPCs deployed in the clouds comprising a multi-cloud computing environment like the environment **500** are communicatively coupled via the global transit layer **108**. Specifically, the VPC **514** of the first cloud is communicatively coupled to the VNET **526** of the second cloud via gateways deployed in each, where such is accomplished through a combination of operations performed by a controller, visibility logic and gateways (e.g., constructs forming the platform **300**). Referring specifically to FIG. **5**, as the controller **502** has launched and deployed the gateways within each of the VPC **514** and the VNET **526**, network traffic may propagate between these constructs (and thus between clouds) while being monitored and controlled by the controller **502**. Further, the VNET **526** (via the gateways deployed therein) may optionally be coupled to additional VPCs or VNETs of other clouds (not shown).

Referring to FIGS. **6A-6B**, a flowchart of a method of automatically building a cloud computing environment is shown in accordance with some embodiments. Each block illustrated in FIGS. **6A-6B** represents an operation performed in the method **600** of automatically building a cloud computing environment by a controller based on received user input. Prior to the start of operations comprising the method **600**, it is assumed that at least one cloud computing account has been established with a first CSP and that a controller instance has been launched and is operationally functional (e.g., processing) on computing resource of the first CSP (the first cloud). In the event multiple CSPs will be utilized in building the cloud computing environment, it is further assumed that the controller has been provided the requisite authentication information for an account with each CSP in order to access the computing resources of the CSP. The method **600** includes operations performed by the controller (e.g., logic of the controller) associated with automatic generation of a cloud computing environment, which includes launching constructs such as VPCs (both spoke and transit) and transit gateways. The method **600** also includes operations of deploying VM instances in the spoke VPCs and establishing communicative connections between transit gateways. Thus, the method **600** generally discloses operations associated with building aspects of a cloud computing environment corresponding to the applications layer **106** and the global transit layer **108** of the architecture **100**.

The method **600** begins when the controller receives user input, via a GUI, corresponding to launching one or more VPCs (block **602**). Thus, a first step in building the applications layer **106** and the global transit layer **108** of a cloud computing environment may be for the controller to launch one or more VPCs, where user input may provide certain parameters such as the cloud type (e.g., CSP), account name for the CSP, a VPC name, a region of the CSP in which to deploy the VPC, and a CIDR for the VPC. Additionally, the VPC type is also indicated per the user input, indicating either a spoke VPC or transit VPC. Upon receiving the user input corresponding to launch one or more VPCs, the controller automatically performs operations to launch the one or more spoke and transit VPCs in accordance with the user input (block **604**). Referring briefly to FIG. **1**, the spoke VPCs may be launched as part of the applications layer **106** (where the spoke VPCs may also be referred to as workload VPCs) and the transit VPCs may be launched as part of the global transit layer **108**.

Referring again to FIG. **6**A, the controller receives user input via a GUI corresponding to launching one or more VM instances within the spoke VPCs (block **606**). Thus, a second step in building the applications layer **106** and the global transit layer **108** of a cloud computing environment may be for the controller to launch one or more VM instances in the spoke VPCs that have been launched in the applications layer **106**. Applications (or processing, workloads, etc.) may process within the VM instances. Upon receiving the user input corresponding to launch one or more VM instances, the controller automatically performs operations to launch the one or more VM instances in accordance with the user input (block **608**).

The method **600** continues with the controller receiving user input via a GUI corresponding to launching one or more transit gateways within the one or more transit VPCs (block **610**). Thus, a third step in building the applications layer **106** and the global transit layer **108** of a cloud computing environment may be for the controller to launch one or more transit gateways, where user input may provide certain parameters such as the cloud type (e.g., CSP), account name for the CSP, a gateway name, a region of the CSP in which to deploy the gateway, a VPC identifier (ID), a public subnet, a gateway size, whether to enable a meshing feature (where primary and backup gateways are both actively used in a load balancing configuration), etc. Upon receiving the user input corresponding to launch one or more transit gateways, the controller automatically performs operations to launch the one or more transit gateways in accordance with the user input (block **612**).

The controller may then receive user input via a GUI corresponding to establishing communicative couplings (connections) between transit gateways (block **614**). Thus, a fourth step in building the applications layer **106** and the global transit layer **108** of a cloud computing environment may be for the controller to connect transit gateways, which may be deployed in across multiple clouds (e.g., provided by multiple CSPs). Upon receiving the user input corresponding to establish connections between transit gateways, the controller automatically performs operations to establish such connections between transit gateways in accordance with the user input (block **616**). These connections allow network traffic to be propagated throughout the entire cloud computing environment. Referring briefly again to FIG. **1**, the transit VPCs, transit gateways and connections therebetween may be launched as part of the global transit layer **108**.

The method **600** continues with the controller receiving user input via a GUI corresponding to launching one or more spoke gateways within the one or more spoke VPCs, and attaching those spoke gateways to transit gateways. This establishes a communicative coupling between spoke VPCs and transit VPCs, e.g., connecting constructs of the applications layer **106** to those of the global transit layer **108** (block **618**). Thus, a fifth step in building the applications layer **106** and the global transit layer **108** of a cloud computing environment may be for the controller to launch one or more spoke gateways, where user input may provide the parameters described above with respect to transmit gateways (blocks **610**-**612**). The user input may provide additional parameters pertaining to establishing the connections between spoke and transit gateways including a spoke gateway name and a transit gateway name between which a connection is to be established. Upon receiving the user input corresponding to launching one or more spoke gateways and attaching those spoke gateways to transit gateways, the controller automatically performs operations to launch the one or more spoke gateways and attached the spoke gateways to transit gateways in accordance with the user input (block **620**).

Additionally, as a set of optional operations, the controller may receive user input corresponding to analyzing the status of connections between gateways (e.g., spoke to spoke via one or more transit gateways), automatically run one or more tests on constructs of the cloud computing environment and provide a graphical display of the test results (block **622**). In one example, the tests may be a "ping" communication sent from a first spoke gateway to a second spoke gateway and the results may include a confirm that a route exists between the two spoke gateways and a latency of the route. Another example of a test may be a "trace route," which includes a transmission sent from a first spoke gateway to a second spoke gateway and the results indicating a number of "hops" (e.g., gateways through which the communication was routed) and a listing of those hops.

Referring to FIG. **7**A, an illustration of a first portion of an example cloud computing environment implemented with the network architecture platform of FIG. **3** including an applications layer and a network layer each of FIG. **1** is shown in accordance with some embodiments. FIG. **7**A illustrates a portion of an exemplary cloud computing environment **700** that has been developed through implementation of the architecture **100**; FIG. **7**B illustrates additional aspects of the cloud computing environment **700**. FIG. **7**A illustrates the deployed constructs situated in either the applications layer **106** or the global transit layer **108**.

The cloud computing environment **700** is shown to span clouds provided by two separate CSPs, namely cloud **702** provided by CSP-1, which includes regions **704**A and **704**B and cloud **706** provided by CSP-**2**. FIG. **7**A also illustrates that the VNET **736** may be connected to additional VPCs (or VNETs), which may be deployed in clouds provided by additional CSPs. Thus, the disclosure is not intended to limit the use of the architecture **100** to two clouds (e.g., provided by two separate CSPs). Instead, the architecture **100** may be utilized to build a cloud computing environment spanning any number of clouds where the constructs of each cloud are communicatively connected within the global transit layer **108**.

In some embodiments, the environment **700** is built automatically by the controller **707** based on user input that may be received via a GUI. One illustrative embodiment of such a methodology is illustrated in FIGS. **6**A-**6**B and discussed above. The discussion of FIGS. **7**A-**7**B may refer to the operations of method **600**, particularly with respect to generation (or building) of the environment **700**. As illustrated, the controller **707** is operating within a VM (not shown) of the VPC **703**, which is deployed within the cloud operations layer **102** utilizing the cloud computing resources of CSP 1 **702**. The VPC **703** also includes visibility logic, which may be operating within a VM (not shown) of the VPC **703**. Further, spoke gateways **708** may be deployed within the VPC **703** in an active-active configuration.

In one exemplary embodiment, the environment **700** is built by the controller **707** based on user input. For example, following establishment of user access accounts with CSP-1 and CSP-2 (and optionally other CSPs), the controller **707** receives authentication information and is configured to access computing resources associated with these accounts. Subsequently, the controller **707** may receive user input indicating spoke VPCs and transit VPCs to be deployed. As a result, the controller **707** deploys the spoke VPCs **710**, **720** and the transit VPCs **716**, **726** in a first cloud **702** provided by CSP-1. Specifically, based on the user input, the spoke VPC **710** and the transit VPC **716** are deployed (or launched) in a first region **704**A (region 1) and the spoke VPC **720** and the transit VPC **726** are deployed (or launched) in a second region **704**B (region 2). Additionally, the controller **707** deploys the spoke VNETs **730**, **732** and the transit VNET **736** in a second cloud **706** provided by CSP-2.

Based on further user input, the controller **707** deploys one or more VM instances (VM instances) **612** in the spoke VPC **610**, VM instances **622** in the spoke VPC **620**, VM instances **631** in the VNET **630** and VM instances **633** in the VNET **632**. Further, the controller **707** launches the transit gateways **718** in the transit VPC **716**, the transit gateways **728** in the transit VPC **726** and the transit gateways **738** in the transit VPC **736**. Additionally, the controller **707** launches the spoke gateways **714** in the spoke VPC **710**, the spoke gateways **724** in the spoke VPC **720** and the spoke gateways **734** in the spoke VPC **732**.

Following launching of the spoke and transit VPCs, the VM instances within the spoke VPCs and the spoke and transit gateways, the controller **707** performs operations to establish communicative connections between: (i) the spoke gateway **714** and the transit gateway **718**; (ii) the spoke gateway **724** and the transit gateway **728**; (iii) the spoke gateway **714** and the transit gateway **718**; (iv) the transit gateway **718** and the transit gateway **728**; and (v) the transit gateway **728** and the transit gateway **738**. Upon establishing such connections, the controller **707** has built the environment **700** in accordance with user input while implementing the architecture **100**.

Referring now to FIG. **7**B, an illustration of a second portion of the example cloud computing environment of FIG. **7**A implemented with the network architecture platform of FIG. **3** including the applications layer, the network layer and a cloud access layer is shown in accordance with some embodiments. The environment **700** of FIG. **7**A is shown as including constructs deployed within the cloud access layer **108**. For example, FIG. **7**B illustrates that the controller **707** may provide access to the computing services of the environment **700** by establishing a connection between the first cloud **602** and the server/network devices of branch offices (or other remote location) **650**. In some embodiments, the connection may be an AWS® Direct Connect circuit between the transit gateway **718** and the spoke gateway **652** deployed on the server/network devices of the branch offices **650**. Similarly, the controller **707** may provide the data center **656** with access to the environment **700** by establishing a connection via the internet between the transit gateway **728** and the data center **656**. Further, the controller **707** may provide the data center **660** with access to the environment **700** by establishing a connection between the transit gateway **728** and the data center **656**, where, in some embodiments, the connection may be an AZURE® ExpressRoute.

Referring to FIGS. **8**A-**8**B, illustrations of example cloud computing environments implemented with the network architecture platform of FIG. **3** including service constructs are shown in accordance with some embodiments. Referring specifically to FIG. **8**A, the cloud computing environment **800** is similar to environments **500** and **700** in that the environment **800** is an environment constructed through implementation of the architecture **100** through the inclusion of a cloud operations layer **102**, an applications layer **106**, a global transit layer **108** and a cloud access layer **110**. Further, the cloud operations layer **102** of the environment includes a "shared services" VPC **802** that includes deployment of VM instances **820** (in which a controller and visibility logic are deployed and operating) and a spoke gateway **822**.

The applications layer **106** of the environment **800** includes a plurality of spoke gateways **804**, **806** and **80**, where each includes a set of VM instances **824**, **828**, **823** and a spoke gateway **826**, **830**, **836**, respectively. Additionally, the global transit layer **108** of the environment **800** includes transit VPCs **810**, **812**. The transit VPC **810** may be referred to as an egress VPC) that includes gateways **838**, **840** and transmit traffic from the environment out to the internet **814** (within the cloud access layer **110**). The transit VPC **812** includes the gateway **842** that is coupled to a F5® SSL ORCHESTRATOR® ("Orchestrator") **844**, which is coupled to a firewall instance **846**. The ORCHESTRATOR® **844** may be configured to decrypt and/or encrypt network traffic passing therethrough, where encrypted network traffic **848** may be passed from a network device **818** through the ORCHESTRATOR® **844**, which decrypts and passes the network traffic to the firewall instance **846** for inspection. The inspected network traffic is then encrypted (network traffic **850**) as it passes through the ORCHESTRATOR® **844** while propagating to the internet via the egress VPC **810**.

As an alternative to transmitting network traffic from the transit VPC **842** to the internet **814** by way of the egress VPC **810**, network traffic may be directed to a data center **816** (where a spoke gateway may be deployed). Thus, FIG. **8**A illustrates one embodiment in which third-party services, e.g., an F5® SSL ORCHESTRATOR®, may be inserted into the global transit layer **108** of an environment constructed in accordance with the architecture **100**.

Referring now to FIG. **8**B, an alternative embodiment of the cloud computing environment **800** is shown in which the transit VPC **812** includes transit gateways **8421**-**8422** deployed in an active-active configuration such that network traffic may be passed back and forth. Additionally, the transit gateways **8421**-**8422** may each be connected to ORCHESTRATOR® instances **8441**-**8444**, which are in turn coupled to firewall instances **8461**-**8464**. In some embodiments, load balancing operations may be performed with network traffic that may be passed to the firewall instances **8461**-**8464** for inspection.

Referring now to FIG. **9**A, an illustration of an example cloud computing environment implemented with the network architecture platform of FIG. **3** including an applications layer and a network layer each of FIG. **1** is shown in accordance with some embodiments. The example cloud computing environment **900** (environment **900**) includes a plurality of regions from a single CSP: Region 1 **902** and Region 2 **904**; however, as indicated in other figures and discussed above (e.g., see FIG. **7**A-**7**B), the disclosure generally, including the embodiment of FIG. **9**A, is not limited to a single CSP. Thus, based on the disclosure throughout, including the description accompanying at least FIGS. **7**A-**7**B, it should be understood that the embodiment of FIG. **9**A may extend to multiple CSPs.

FIG. **9**A illustrates a portion of environment **900** that has been developed through implementation of the architecture **100**; FIGS. **9**B-**9**D illustrate visualizations accessible via the controller **908** and/or the visibility logic **304**. For example, the visualizations may be accessible by a network administrator through a web browser and/or a dedicated application interface ("app") that operates, at least partially, on a network device of the administrator.

The cloud computing environment **900** is shown to include a cloud that spans two regions, namely region 1 **902** and region 2 **904** provided by CSP-1; not shown are optional additional clouds provided by other CSPs that may be communicatively coupled to the illustrated network constructs at least via the global transit layer **108** (see fragmented connection line). As noted, the disclosure is not intended to limit the use of the architecture **100** to any number of clouds (e.g., provided by one or more CSPs). Instead, the architecture **100** may be utilized to build a cloud computing environment spanning any number of clouds where the constructs of each cloud are communicatively connected within the global transit layer **108**.

In some embodiments, the environment **900** is built automatically by the controller **908** (deployed in the VPC **906**, alongside the visibility logic **304**, where the VPC **906** may include the spoke gateway(s) **910**) based on user input that may be received via a GUI. One illustrative embodiment of such a methodology is illustrated in FIGS. **6**A-**6**B and discussed above. The generation of the environment **900** may be similar to that of the environment **700** discussed above, albeit with different network constructs. FIG. **9**A includes additional details such as network address information (e.g., IP addresses and/or CIDRs) of a plurality of the network constructs. For instance, the VPCs **912**, **914** deployed may have the CIDRs of 10.90.0.0/16, 10.91.0.0/16, respectively. Similarly, the VPCs **916**, **922** may have the CIDRs of 10.100.0.0/16, 10.101.0.0/16, respectively. Further, the VPCs **926**, **932** may have the CIDRs of 10.105.0.0/16, 10.106.0.0/16, respectively.

As discussed above, the controller **908** is configured to deploy the majority, if not all, of the network constructs shown in FIG. **9**A and thus has visibility as to the network address information (hereinafter, generally "CIDRs" for clarity) of each network construct. For instance, the controller **908** may maintain a listing of all transit gateways deployed within the environment **900** (see FIG. **9**B) and generate various visualizations display details of the transit gateways, associated connections and other network constructs (see FIGS. **9**B-**9**D). As noted below, the visualizations may alternatively be generated by the visibility logic **304** and/or the visualizations may be generated by the combination of the controller **908** and the visibility logic **304**.

More specifically, the controller **908** may be configured to obtain routing information (also referred to as "learning" routes or routing information) pertaining to the propagation of network traffic through the environment **900**. As the controller **908** learns routing information from one construct, e.g., the transit gateway **942**, such may be propagated to network constructs, e.g., the controller **908** may program the routing tables of network constructs to include routing information learned from another network construct. In some embodiments, the controller **908** may learn routing information from spoke or transit gateways and/or from native constructs (such as AWS® transit gateways, e.g., the gateway **938**).

For instance, as the controller **908** monitors network traffic flow throughout the environment **900**, with may include obtaining data from the visibility logic **304**. For example, the controller **908** may maintain construct metadata, which may include, but is not limited or restricted to one or more of the following construct parameters (properties) for each construct: construct name, construct identifier, encryption enabled, properties of the VPC associated with that construct (e.g., VPC name, identifier and/or region, etc.), cloud properties in which the construct is deployed (e.g., cloud vendor in which the construct resides, cloud type, etc.), or the like. Additionally, the visibility logic **304** may query certain network constructs, such as gateways, via APIs calls to obtain network data (e.g., for each network packet, but is not limited or restricted to, an ingress interface, a source IP address, a destination IP address, an IP protocol, a source port for UDP or TCP, a destination port for UDP or TCP, a type and code for ICMP, an IP "Type of Service," etc.). Additional detail regarding obtaining construct metadata and network data may be found in U.S. patent application Ser. No. 17/006,657, titled "System and Method for Determination of Network Operation Metrics and Generation of Network Operation Metrics Visualizations," filed Aug. 28, 2020, the entire contents of which have been previously incorporated herein by reference.

Based on monitoring the network traffic and the network constructs at least by obtaining and maintaining construct metadata and network data, the controller **908** may maintain a status of each construct within the environment **900** and learn routing information between constructs.

For example, the controller **908** may maintain routing information indicating how network traffic propagates from the transit gateways **928** (e.g., two deployed in HA mode, whereas a single gateway icon is illustrated due to space constraints) within the VPC **926** to the transit gateways **942** (e.g., two deployed in HA mode) within the VPC **940**. This routing information may include any networking tunnels (e.g., IPSec or BGP tunnels) that may have been established between the transit gateways **942** and the transit gateways **946** (e.g., two deployed in HA mode). FIGS. **9**C-**9**D illustrate exemplary gateway details for a selected gateway including routing information including an indication a destination for network traffic, a "via" column indicating an IP address through which a network may pass when propagating from the selected gateway to the corresponding destination, any networking tunnels that may be utilized (e.g., tunnel name: "tun-**0**A640038-**0**" of FIG. **9**D), a "next hop IP" address, a "next hop gateway" and a status of the corresponding route (e.g., a row of the routing table **964**).

Additionally, the controller **908** also maintains certain gateway information of a selected gateway (e.g., "AWS West Transit GW") in FIG. **9**C pertaining to either of the transit gateways **942** of the VPC **940**. For example, the listing **962** of FIG. **9**C includes information maintained by the controller **908** such as names of on-prem connections ("West2-Colo" and "West2-Colo-Xing"), a spoke peer list ("West2-VPC1-GW" and "West2-VPC2-GW") and a transit peering list ("Azure-West-Transit-GW" and "Azure-East-Transit-GW", which are regions of a cloud by a second CSP not shown in FIG. **9**A, wherein CSP-1 may be refer to AWS® and the second CSP may refer to AZURE®; however, other CSPs may be utilized). Thus, FIG. **9**C illustrates that controller **908** provides to the gateway **942** certain routing information. As further shown in FIG. **9**C, listings of CIDRs accessible to the gateway **942** (in some instances, directly accessible via a single hop) may also be provided by the controller **908** to the gateway **942**, which may indicate native constructs to which the gateway **942** is attached (or otherwise in communication) (e.g., TGW CIDRs 10.91.0.0/16, 10.90.0.0/16, which refer to the native VPCs **912**, **914** and constructs deployed therein).

Additionally, one listing of CIDRs accessible to the gateway **942** may also be provided by the controller **908** to the gateway **942** may indicate constructs to which the gateway **942** is communicatively coupled to via transit peering (e.g., via an intermediary transit gateway) (e.g., Transit Peering Site CIDRs 10.106.0.0/16, 10.105.0.0/16, which refer to the VPCs **926**, **932** and constructs deployed therein).

Generally, as constructs are deployed or go offline and the environment **900** is altered, so too is the routing information of environment **900**. Thus, the controller **908** may continually, e.g., a regular intervals or in response to certain user input, provide updated routing information to gateways deployed within the environment **900** thereby updating the "gateway detailed information," an example of which is illustrated in FIG. **9**C and/or a gateway's routing table, an example of which is illustrated in FIG. **9**D.

Referring to FIG. **9**B, an exemplary illustration of a first visualization of a transit network visualization **952** generated by the visibility logic **304** is shown in accordance with some embodiments. In some embodiments, the transit network visualization **952** may be generated by the visibility logic **304**. However, in other embodiments, the controller **908** may obtain any requisite data from the visibility logic **304** and generate the transit network visualization **952** (and the display portions discussed herein). The transit gateways listed in the display portion **958** include those deployed in the environment **900**.

As shown, the transit network visualization **952** includes a main display portion **954** and a navigation panel **956**. The main display portion **954** may include a plurality of display portions **958**-**960** with the display portion **958** including a listing of transit gateways deployed within the example cloud computing environment **900** of FIG. **9**A. Additionally, the display portion **960** includes similar content as the listing of the display portion **958**; however, a header is shown within additional rows for purposes of clarity. The listing of the display portion **958** includes a header, which provides an indication of the content of the rows of the listing, which include certain data pertaining to transit gateways: name, state, VPC CIDRs, HA mode (where HA refers to "high availability"), connection. For example, referring to row **959**, which appears in a highlighted manner (e.g., rendered in a visually distinct manner from other rows) includes a name of "AWS WEST-TRANSIT GW", has a state of "UP" (e.g., its status is "up" or "active"), has a VPC Classless Inter-Domain Routing (CIDR) address of 10.102.0.0/16, has a HA mode of "ACTIVEMESH" (meaning two transit gateways are deployed within the corresponding VPC in an active-active configuration where both transit gateways may receive network traffic for routing), and Connection status of "YES" (which may indicate that the controller **908** is connected to the transit gateway).

The transit network visualization **952**, through various display portions, may be configured to receive user input, such as selections of content (e.g., a particular row of the listing within the display portion **958**, e.g., "AWS WEST-TRANSIT GW"). Upon receipt of user input indicating selection of content, e.g., "AWS WEST-TRANSIT GW," additional visualizations may be generated or otherwise caused to be rendered, where examples of such additional visualizations may include FIGS. **9**C-**9**D.

Referring now to FIG. **9**C, an exemplary illustration of a second visualization of the transit network visualization **952** generated by the visibility logic **304** is shown in accordance with some embodiments. The second visualization includes the listing **962** of information provided to the selected gateway (e.g., "AWS West Transit GW") that is maintained by the controller **908**. Details of the listing **962** and its relationship to the environment **900** of FIG. **9**A is discussed above.

Referring now to FIG. **9**D, an exemplary illustration of a third visualization of a transit network visualization **952** generated by the visibility logic **304** is shown in accordance with some embodiments. As discussed above in combination with the discussion of FIG. **9**A, the route table **962** may be programmed by a controller, e.g., the controller **908**, to include routing information learned by the controller **908** through deploying constructs, monitoring the constructs and monitoring network traffic, optionally in combination with the visibility logic **340**.

In the foregoing description, the invention is described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A distributed cloud computing system built in accordance with a repeatable network architecture, the distributed cloud computing system comprising:

a controller;

a first set of spoke gateways; and

a first transit gateway;

wherein the controller is configured to:

deploy the first set of spoke gateways in a first cloud of a first cloud service provider (CSP) thereby forming an applications layer of the repeatable network architecture;

deploy the first transit gateway in the first cloud thereby forming a global transit layer of the repeatable network architecture;

wherein the applications layer and the global transit layer form a cloud core layer configured to be communicatively coupled to a cloud operations layer and a cloud access layer, the cloud access layer comprising constructs that provide network devices with access to constructs within the cloud core layer;

establish communicative couplings between each of the first set of spoke gateways and the first transit gateway; and

duplicate at least one construct from deployment in the first CSP to deployment in a second CSP, wherein the at least one construct and the duplicated construct are configured for use with constructs of the cloud operations layer and the cloud access layer,

wherein the controller operates as a single instance that is deployed in the first CSP and is configured to receive authentication credentials from a user to access a cloud provided by the second CSP.

2. The distributed cloud computing system of claim **1**, wherein the controller is configured to deploy a first set of spoke virtual private clouds (VPCs) within the first cloud, wherein each of the spoke VPCs has deployed therein one of the first set of spoke gateways.

3. The distributed cloud computing system of claim **2**, wherein the controller is configured to deploy a first transit VPC within the first cloud, wherein the first transit gateway is deployed in the first transit VPC.

4. The distributed cloud computing system of claim **1**, wherein the second CSP has a different number of constructs than the first CSP.

5. The distributed cloud computing system of claim **1**, further comprising:

a second set of spoke gateways; and

a second transit gateway;

wherein the controller is configured to:

deploy the second set of spoke gateways in a second cloud thereby extending the applications layer of the repeatable network architecture to the second cloud;

deploy the second transit gateway in the second cloud thereby extending the global transit layer of the repeatable network architecture to the second cloud; and

establish communicative couplings between each of the second set of spoke gateways and the second transit gateway.

6. The distributed cloud computing system of claim **5**, further comprising:

logic, stored on non-transitory, computer-medium, that, upon execution by one or more processors, causes performance of operations including:

receiving network traffic at the first transit gateway originating from a spoke VPC of the first set of spoke VPCs deployed in the first cloud;

routing the network traffic from the first transit gateway to the second transit gateway deployed in the second cloud; and

routing the network traffic to a destination VPC deployed within the second cloud, wherein the destination VPC is one of a second set of spoke VPCs.

7. The distributed cloud computing system of claim **1**, further comprising:

visibility logic deployed in a virtual machine instance within a cloud operations layer of the first cloud, wherein the visibility logic is stored on non-transitory, computer-medium, and upon execution by one or more processors, causes performance of operations including:

receiving, from the controller, metadata pertaining to a plurality of gateways deployed in the first cloud and a second cloud;

receiving, from each of the plurality of gateways, network data, wherein a combination of the metadata and the network data identify each of a plurality of constructs deployed in the first cloud and the second cloud, communication paths between each construct, and in which cloud each construct is deployed;

generating a visualization illustrating the plurality of constructs and the communication paths therebetween; and

causing rendering of the visualization on a display screen of a network device.

8. The distributed cloud computing system of claim **1**, wherein the controller programs a routing table of the first transit gateway with routing information obtained through monitoring at least one of network constructs or network traffic within the distributed cloud computing system.

9. A method for building a distributed cloud computing system in accordance with a repeatable network architecture, the method comprising:

deploying, by a controller of the distributed cloud computing system, a first set of spoke gateways in a first cloud thereby forming an applications layer of the repeatable network architecture;

deploying, by the controller, a first transit gateway in the first cloud thereby forming a global transit layer of the repeatable network architecture;

wherein the applications layer and the global transit layer form a cloud core layer configured to be communicatively coupled to a cloud operations layer and a cloud access layer, the cloud access layer comprising constructs that provide network devices with access to constructs within the cloud core layer;

establishing, by the controller, communicative couplings between each of the first set of spoke gateways and the first transit gateway; and

duplicating, by the controller, at least one construct from deployment in a first cloud service provider (CSP) to a second CSP, wherein the at least one construct and the duplicated construct are configured for use with constructs of the cloud operations layer and the cloud access layer,

wherein the controller operates as a single instance that is deployed in the first CSP and is configured to receive authentication credentials from a user to access a cloud provided by the second CSP.

10. The method of claim **9**, wherein a controller, deployed within a cloud operations layer of the first cloud, is configured to deploy the first set of spoke gateways, deploy the first transit gateway and establish the communicative couplings therebetween.

11. The method of claim **9**, further comprising:

deploying, by the controller, a first set of spoke virtual private clouds (VPCs) within the first cloud, wherein each of the spoke VPCs has deployed therein one of the first set of spoke gateways.

12. The method of claim **11**, wherein the controller is configured to deploy a first transit VPC within the first cloud, and wherein the first transit gateway is deployed in the first transit VPC.

13. The method of claim **12**, further comprising:

wherein the second CSP has a different number of constructs than the first CSP.

14. The method of claim **9**, further comprising:

deploying, by the controller, a second set of spoke gateways in a second cloud thereby extending the applications layer of the repeatable network architecture to the second cloud;

deploying, by the controller, a second transit gateway in the second cloud thereby extending the global transit layer of the repeatable network architecture to the second cloud; and

establishing, by the controller, communicative couplings between each of the second set of spoke gateways and the second transit gateway.

15. The method of claim **14**, further comprising:

receiving, by the controller, network traffic at the first transit gateway originating from a spoke VPC of the first set of spoke VPCs deployed in the first cloud;

routing, by the controller, the network traffic from the first transit gateway to the second transit gateway deployed in the second cloud; and

routing, by the controller, the network traffic to a destination VPC deployed within the second cloud, wherein the destination VPC is a VPC of a second set of spoke VPCs.

16. The method of claim **9**, further comprising:

receiving, by visibility logic deployed in a virtual machine instance within a cloud operations layer of the first cloud from the controller, metadata pertaining to a plurality of gateways deployed in the first cloud and the second cloud;

receiving, by the visibility logic from each of the plurality of gateways, network data, wherein a combination of the metadata and the network data identify each of a plurality of constructs deployed in the first cloud and the second cloud, communication paths between each construct, and in which cloud each construct is deployed;

generating, by the controller, a visualization illustrating the plurality of constructs and the communication paths therebetween; and

causing, by the controller, rendering of the visualization on a display screen of a network device.

17. The method of claim **9**, further comprising:

programming, by the controller, a routing table of the first transit gateway with routing information obtained through monitoring at least one of network constructs or network traffic within the distributed cloud computing system.

18. A non-transitory computer-readable medium having stored thereon logic that, when executed by one or more processors, causes operations including:

deploying, by a controller of the distributed cloud computing system, a first set of spoke gateways in a first cloud thereby forming an applications layer of a repeatable network architecture;

deploying, by the controller, a first transit gateway in the first cloud thereby forming a global transit layer of the repeatable network architecture;

wherein the applications layer and the global transit layer form a cloud core layer configured to be communicatively coupled to a cloud operations layer and a cloud access layer, the cloud access layer comprising constructs that provide network devices with access to constructs within the cloud core layer;

establishing, by the controller, communicative couplings between each of the first set of spoke gateways and the first transit gateway; and

duplicating, by the controller, at least one construct from deployment in a first cloud service provider (CSP) to a second CSP, wherein the at least one construct and the duplicated construct are configured for use with constructs of the cloud operations layer and the cloud access layer,

wherein the controller operates as a single instance that is deployed in the first CSP and is configured to receive authentication credentials from a user to access a cloud provided by the second CSP.

19. The non-transitory computer-readable medium of claim **18**, wherein a controller, deployed within a cloud operations layer of the first cloud, is configured to deploy the first set of spoke gateways, deploy the first transit gateway and establish the communicative couplings therebetween, and further comprising:

deploying, by the controller, a first set of spoke virtual private clouds (VPCs) within the first cloud, wherein each of the spoke VPCs has deployed therein one of the first set of spoke gateways; and

programming, by the controller, a routing table of the first transit gateway with routing information obtained through monitoring at least one of network constructs or network traffic within the distributed cloud computing system.

20. The non-transitory computer-readable medium of claim **18**, wherein the controller is configured to deploy a first transit VPC within the first cloud, wherein the first transit gateway is deployed in the first transit VPC, and further comprising:

deploying, by the controller, a second set of spoke gateways in a second cloud thereby extending the applications layer of the repeatable network architecture to the second cloud;

deploying, by the controller, a second transit gateway in the second cloud thereby extending the global transit layer of the repeatable network architecture to the second cloud; and

establishing, by the controller, communicative couplings between each of the second set of spoke gateways and the second transit gateway.

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